KENYATTA UNIVERSITY

SCHOOL OF AGRICULTURE AND ENTERPRISE DEVELOPMENT

2^{ND} BIENNIAL INTERNATIONAL CONFERENCE ON ENHANCING SUSTAINABLE AGRICULTURAL PRODUCTION AND MARKETING SYSTEMS

HELD FROM 29^{TH} NOVEMBER TO 2^{ND} DECEMBER 2016
AT BUSINESS AND STUDENT SERVICES CENTER,
KENYATTA UNIVERSITY

Edited by Waceke Wanjohi, Daniel Kyalo Willy, Purity Nguhiu and Cyrus Gichaga

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PROCEEDNGS OF THE 2ND BIENNIAL INTERNATIONAL CONFERENCE ON ENHANCING SUSTAINABALE AGRICULTURAL PRODUCTION AND MARKETING SYSTEMS THROUGH SCIENCE, TECHNOLOGY AND INNOVATIONS

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PREFACE

The agricultural sector remains a key pillar to economic development in Sub-Saharan Africa and other developing regions. In Kenya for instance, agriculture is one of the key sectors, accounting for 25% of the gross domestic product (GDP). The sector also accounts for 65 per cent of Kenya's total exports and provides more than 18% and 75% of formal and informal employment respectively. The growth of the national economy is therefore highly correlated with agricultural growth and development. The sector is however faced by a battery of challenges, limiting its potential to play this critical role. The challenges include limited use of modern agricultural technologies extreme weather events, deterioration in soil fertility, post harvest losses and poor access to agricultural extension services. As a result of these challenges, agricultural productivity has been low and agriculture dependent households continue to be impoverished. It is therefore critical that efforts by the government of Kenya in collaboration with other key stakeholders such as research institutes, universities and other collaborators should focus on addressing these challenges.

In line with this agenda, the School of Agriculture and Enterprise Development (SAED), Kenyatta University organizes a Biennial Conference every two years. This offers an opportunity to various stakeholders in Agricultural sector to share and exchange knowledge and experiences. The SAED Biennial conference also provides a platform for developing networks between individuals and institutions, through which capacity and expertise can be shared to spur development and address the challenges affecting the Agricultural sector.

The second conference was organized in collaboration with World Vision Kenya. It brought various stake holders in agriculture from Kenya and other African countries. The deliberations centered on the theme "Enhancing sustainable agricultural production and marketing systems through science, technology and innovation".

We are therefore pleased to present the book of proceeding of the 2nd SAED Biennial Conference which was held form 29th November to 2nd December, 2016 at Kenyatta University, Nairobi, Kenya. The conference received an overwhelming number of scientific papers cutting across varied themes. These papers are contained in this book of proceedings and therefore will be of interest to wide readership.

Acknowledgement

This conference was organized jointly between Kenyatta University School of Agriculture and Enterprise development and World Vision-Kenya. The organizing committee wishes to sincerely appreciate the support from the management of Kenyatta University and World Vision-Kenya for their invaluable support during the planning and hosting of the conference. The contribution by members of staff from both Kenyatta University and World Vision-Kenya in various capacities is highly appreciated. We are

indebted to all conference national and international participants, who submitted quality scientific papers which culminated into a successful conference.

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WELCOMING REMARKS BY THE DEAN, SAED

Prof. Waceke Wanjohi, PhD.
FRSB, FKNAS
Dean, School of Agriculture and Enterprise

It gives me great pleasure to warmly welcome you to the 2nd SAED Biennial Conference taking place from today the 29th November 2016 to 2nd December 2016 at the Business and Students' Services Center, Kenyatta University, Nairobi Kenya. In 2012, the School of Agriculture Board of the then 4 year old School made a bold decision to be holding biennial conferences with the primary aim of creating a platform to disseminate research findings; bringing various actors in the industry together for dialogue and enhancing the visibility of the young School. In 2014, we held a successful 4 days inaugural conference and I am happy that the Conference is now fully integrated in the school calendar.

The overall theme of the conference is "*Enhancing Sustainable Agricultural Production and Marketing Systems*".

It is notable that though agriculture contributes 25% of the GDP, employs over 70% of the workforce and is key in the attainment of the middle income economy, its characterized by low productivity (both in terms of low return to land and labour). Raising agricultural productivity in a sustainable way remains therefore a major national focus as captured in the Kenya Development blue print; the Kenya Vision 2030. The high food losses (54%) at the production, postharvest handling and storage stages and the high food wastages (46%) at the processing, distribution and consumption stages further aggravates the matter. According to a recent FAO report, a staggering 1.3billion tonnes of food per year is wasted leading to economic losses in the tune of USD 750 billion (75trillion) annually and adding 3.3billion tonnes of greenhouse gases hence negatively affecting the environment.

Compounding this challenge is the aging farming population in that the average farmer in Kenya today is 60 years old against a life expectancy of 63 years while the youth comprising 33% of the Kenyan population have in general a negative attitude towards agriculture. Given the slow economic development pace in Kenya, it is hard to expect the industry and service sectors to grow substantially to absorb all the youths entering the job market. Therefore, agriculture, the alternative sector, has to play a critical role of providing employment opportunities to the youths. Increasing commercial viability of agricultural enterprises so as to make agricultural returns attractive is also critical. Successful agribusiness investments stimulate agricultural growth through the development of new markets and a vibrant input supply sector. For this reason the School of Agriculture has focused on rebranding the curriculum to make it attractive to the youth, with an emphasis on agriculture as a business and promotes and supports the engagement of the youth in agriculture through various innovative initiative. Though technologies to enhanced sustainable agricultural production systems have been developed, the diffusion of technology in Kenya has been slow.

Further, due to infrastructural challenges, incidences of high (market) transaction costs are rampant and often leads to market failure. In addition, most small holder farmers also are not fully integrated into high value markets so as to take advantage of globalization of agricultural value chains.

This conference therefore brings together the practitioners in agriculture, policy makers, research institutions, civil society and the private sector to deliberate on the challenges revolving around these key challenges. The dialogue will revolve around five subthemes namely:

Subtheme 1: Crop management, Biotechnology and Climate change

Management of Emerging Crop Pests and Diseases, Emerging issues in Agricultural Biotechnology, building farmer resilience and risk management strategies in the wake of climate change.

Subtheme 2: Livestock production and health issues

Strengthening Integrated Crop and Livestock production systems, Enhancing Livestock productivity through Improved Livestock health and new production techniques.

Subtheme 3: Technology diffusion, Impact and Sustainable Agribusiness value chains:

Facilitating access to technology, fast adoption and diffusion of Innovations in Agricultural Value chains, building environmental sensitive agribusiness value chains, Agricultural commercialization and Impact of agricultural innovations on farmer outcomes.

Subtheme 4: Soil health management, Input access and Conservation issues:

Integrated strategies for enhancing Soil health, Soil and Water Conservation and enhancing performance of irrigated agriculture, yield response to fertilizer use and Innovative strategies for facilitating input access.

Subtheme 5: Emerging and Topical issues in Agriculture

Agricultural Innovations, ICT Applications in Agriculture & Agribusiness, Youth involvement in Agri-preneurship, Mobile phone applications in Agriculture, Gender issues in Agriculture, Access to resources and women Participation in commercial agriculture.

The aims of this conference are fivefold; share research findings which seek to address some of the major challenges affecting the agricultural Sector with a broad audience; bring various actors in the industry together for dialogue and for networking; provide a platform for mentoring upcoming research scientists; create an opportunity for the players in the sector to exhibit their services and products and strengthen engagement and linkage between the actors in the industry and the School of Agriculture.

Partnering with us in organizing this conference is the World Vision Kenya; an Organization which is very well known by the audience having been in existence since 1950 and with significant impact.

The 2016 SAED Biennial conference has attracted participants and exhibitors from different organizations and comprises of 4 plenary sessions, six parallel sessions and exhibitors' session. It is therefore my hope that you will make the most of this conference as you interact and learn from this diverse audience.

On my own behalf and on behalf to the entire School, I once again welcome you to the 2nd SAED Biennial Conference and wish you fruitful deliberations and engagement.

ABOUT THE CONFERENCE ORGANIZERS

Kenyatta University, School of Agriculture and Enterprise Development (SAED)

Kenyatta University, School of Agriculture and Enterprise Development was established in December, 2007 in response to the growing need of competent leaders who can meet the rapidly changing market demand in the Agricultural related sectors and to contribute in the achievement of Kenya's Blue Print Vision 2030. Agriculture is one of the six components under the economic pillar to deliver 10% economic growth per annum. The School provides an enabling environment for academic excellence, research and community engagement with a focus to producing socially responsible, highly motivated and responsive professionals with a significant outlook and perspective to potentials and challenges in Agriculture. The school has a strong emphasis on agribusiness. The objectives of the school are to: (i) Re-orient the training of agricultural scientists to encompass coordinated pluralism that integrates a wide range of specializations including enterprise development in Agriculture. (ii) Promote agricultural theory and practice as a business for sustainable development. (iii) Promote the primacy of agriculture in sustainable socio- economic development. (iv) To promote partnership, networking and collaboration with the Public and Private sectors at the all levels. (v) To create a conducive environment for teaching, learning and carrying out research in agriculture. (vii) To provide consultancy services in major areas of agriculture.

World Vision Kenya

Founded in 1950, World Vision is an international partnership of Christians serving children, their families and communities in conditions of poverty in nearly 100 countries, primarily through programmes of community development, disaster management and promotion of justice.

World Vision began operations in Kenya in 1974. Its more than 800 committed development staff members work in 52 Area Development Programmes in 35 counties country-wide. Through valued partnerships, World Vision Kenya supports communities to access the knowledge and resources needed to improve the well-being of children and overcome poverty. World Vision has four strategic goals regarding the well-being of children:

(i) Children enjoy good health. (ii) Children are educated for life. (iii) Children experience the love of God and their neighbours, always being mindful that World Vision is a guest in cultures that hold many diverse beliefs. (iv) Children are cared for, protected and participating in the decisions that affect their lives.

World Vision Kenya works with the most vulnerable children and communities regardless of religion, race, ethnicity or gender.

Vision Statement: Our vision for every child, life in all its fullness; Our prayer for every heart, the will to make it so.

Mission: World Vision is an international partnership of Christians, whose mission is to follow our Lord and Saviour Jesus Christ, in working with the poor and oppressed to promote human transformation, seek justice and bear witness to the good news of the Kingdom of God.

Our Core Values: We are Christian | We are committed to the poor | We value people | We are stewards | We are partners | We are responsive

PROFILE OF THE CHIEF GUEST

Prof. Paul K. Wainaina
AG. Vice Chancellor,
Kenyatta University

Prof. Paul Wainaina is a Professor of Philosophy at Kenyatta University. He holds Bachelor of Education (Honors) from the University of Nairobi. He completed his graduate training from the same University where he obtained his MA majoring in Philosophy of Education. He later completed his PhD in Philosophy of Education from the University of Alberta, Canada where his research focus was on axiological and epistemological foundations of education. He is a keen philosopher with extensive research work on Ethics in Education. Prof. Wainaina has risen through the academic ranks; from Lecturer to Full Professor. He has been elected Dean, Faculty of Education, University of Namibia, in the Republic of Namibia.

Prior to his appointment as acting Vice Chancellor, Kenyatta University, Prof. Wainaina has served in various positions within Kenyatta University including being a member of the Kenyatta University Management Board and University Council. He has also served as a member of the Kenyatta University Staff Pension Scheme as well as Acting Deputy Vice Chancellor (Administration), Acting Deputy Vice-Chancellor (Academic Affairs), and Deputy Vice Chancellor (Administration), Kenyatta University.

PROFILES OF KEYNOTE SPEAKERS

Prof. Gituro Wainaina, Associate Professor, School of Business - University of Nairobi & Former Ag. Director General, Vision 2030 Secretariat

Prof. Wainaina is a PhD holder in Agricultural Economics, Master in Business Administration, Bachelor of Education and Associate Professor in the School of Business University of Nairobi. He has extensive working experience with University of Nairobi where he is an Associate Professor, Kenya Vision 2030 Delivery Secretariat where he was Acting Director General as well as Director for Social and Political Pillars, World Bank where he was a Senior Education Economist, CARE International in Kenya where he was Regional Coordinator and University of Nairobi Enterprises and Services Limited, where he was Deputy Managing Director and Business Development Manager.

I have been a board member of Capital Market Authority, Lamu Port South Sudan and Ethiopia Transport Corridor. Presently, I am a council and board member of Management University of Africa, council member of Riara University, alternate board member for Africa Group B Partnership in Statistics for Development in the 21st Century under Organization for Economic Co-operation and Development, and a member of Uwezo Kenya National Advisory Committee.

Mr. Jeremiah Nyaga Operations Director, World Vision Kenya

Jeremiah Nyagah, is the Operations Director of World Vision Kenya, "a Christian relief and development organization dedicated to promoting the well-being of children, families and communities around the world. Jeremiah is a project management specialist with holistic management experience gathered over 17 years in Programme management, Design, Monitoring & Evaluation (DM&E), Change management and leadership. He has had a successful career in humanitarian programming, having worked with Pathfinder International, Child Fund (CCF then) and now with World Vision. He joined World Vision Kenya as an Area Development Programme Manager and has served in other roles over the years; which include Regional DM & E Coordinator, National Transformational Development Indicators Measurement Coordinator, National DM & E Coordinator and Associate Program's Director. Jeremiah assumed the role of the Operations Director in October 1, 2015.

Jeremiah is a Bachelor of Education graduate from Egerton University. He obtained a postgraduate degree in Development studies from the University of South Africa (UNISA). In addition he has a Master's degree in Organizational Leadership from Africa International University.

Dr. Everline Namubiru Mwaura,
Strategy and Policy Manager

Evelyn Namubiru-Mwaura has over fifteen years of experience in international development, strategy and governance through appointments with AGRA, the World Bank, UNREDD, UNDP-GEF, International Forestry Resources and Institutions (IFRI) and Makerere University. She provides policy and strategic leadership in the development and delivery of AESA's scientific agenda for Africa. The holder of a PhD in public policy from Indiana University in the US has won several awards including the Elinor Ostrom-Johan Skytte Fellowship, the International Foundation for Science award for field research, and the Compton Foundation Peace & Security Fellowship and the Australian Sponsored Training Scholarship.

Mr. Tennyson Williams,
Regional Director for Africa,
World Animal Protection

Mr. Tennyson Williams, a skilled leader and manager with experience spanning more than 15 years in INGO management and leadership. As, an international development specialist with a background in zoology and zoonotic diseases, Tennyson has held a number of senior management positions directing Africa-wide regional programmes with multi-donor funding. Originally from Sierra Leone, he was until joining World Society for the Protection of Animals (WSPA) the ActionAid Kenya Country Director responsible for directing programmes, policy and advocacy, and shaping the development of the organization in Africa as well as internationally.

Prior to that, he was ActionAid International Director for West and Central Africa with strategic leadership, governance and programme oversight responsibilities in Burundi, Democratic Republic of Congo, Ghana, Liberia, Nigeria, Rwanda, Senegal, Sierra Leone and The Gambia. Before that he was ActionAid Country Director for Sierra Leone focusing on poverty reduction and humanitarian influence and credibility, and driving forward WSPA's campaigns and programmes, particularly in the areas of Disaster Management, Humane and Sustainable Agriculture, Ending Inhumane Culling and Wild Life.

PROFILES OF EXHIBITORS

The conference attracted eighteen (18) organizations who participated in the exhibitions category. These were drawn from a wide range of organiozations enganged in different activities cutting across the agricultural value chain: Agro-input producers and marketers, Regulators, Financial Institutions, Farmer and Community development groups, Non-Governmental Organizations and Research Organizations. Below are profiles of some of the exhibitors;

Biovision Africa Trust (BvAT)

Biovision Africa Trust (BvAT) is a not-for-profit organization established in Kenya in 2009 by the Biovision Foundation for ecological development in Switzerland and supported by the International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi. The Trust's goal is to alleviate poverty and improve the livelihoods of smallholder farmers by supporting dissemination of information and knowledge on appropriate technology to improve human, animal, plant, and environmental health.

The **overall goal** of the Trust is to sustainably improve the lives of the people in Africa while conserving the environment as the basis for all life

Our vision is a food secure African continent with healthy people living in a healthy environment. The trust runs several projects to help it achieve its objectives:

- The organic farmer magazine
- The organic farmer radio
- Outreach project

For more information please visit: www.Infonet-biovision.org

Centre for Agriculture and Biosciences International (CABI)

CABI is an international not-for-profit organization that improves people's lives worldwide by providing information and applying scientific expertise to solve problems in agriculture and the environment. Our approach involves putting information, skills and tools into people's hands. CABI's 48 member countries guide and influence our work which is delivered by scientific staff based in our global network of centres.

CABI is also a leading global publisher producing key scientific publications, including the world renowned **CAB Abstracts** (the leading abstracting and indexing database in the applied life sciences), **Global Health**, as well as Compendia, books, eBooks and full text electronic resources. Behind each of our products is a team of subject specialists committed to delivering the most relevant and authoritative information to researchers worldwide. We also offer **CAB Direct**, CABI's online development platform, providing a single point of access to all your CABI database subscriptions. CABI has over 100 years' experience in scientific publishing.

Monitoring and Evaluation Food Security Programme (MEFOSEP)

MEFOSEP established a food security monitoring information system, by using anotice board which provides a target plan and updated information based on the actual findings that are taking place among the farmers in the community. MEFOSEP have upgrade this system to use of a mobile app to know the right spacing required and to calculate for farmers on the quantity of farm inputs (fertilizers, manure and seeds) they need and the expected yield once they insert the acreage of land and the recommended fertilizer after conducting soil test analysis. It also monitors famer's production activities. These information from the app is relayed into a central server system which aggregates it and update it on the notice board.

Objectives:

1 To improve on preparedness to mitigate agricultural challenges by undertaking timely (early) warning through sequential disseminating information on the actual outcome of each season on the notice board and providing intervention in the published articles and in the website blog for discussion.

2 To improve food security by identifying food security gaps through data analysis and participatory dialogue meeting with the farmers, agricultural staffs to compare each seasons with other previous seasons and the target plan.

Agrochemicals Association of Kenya (AAK) / CropLife Kenya

The Agrochemicals Association of Kenya (AAK) is the national representative of the International Agrochem Industry represented worldwide by CropLife International. AAK is the umbrella organisation in Kenya for manufacturers, formulators, repackers, importers, distributors, farmers and other users of pest control products. The association has been in existence since 1958 under various names with the most recent one being Pesticide Chemicals Association of Kenya (PCAK).

The objectives of the association are: Promotion and public education on the safe and responsible use of pesticides, providing an agency for liaison with government and other stakeholders on matters of mutual interest, promote just, fair and honourable trade practices among its members while weeding out counterfeits, encourage research in areas that will improve pesticide use as well as work with regulators on labelling, registration and taxation of pesticides.

Twaweza Initiative

Twaweza initiative is a young women group founded in the year 2010. The group is found in Korogocho- Kariobangi slum in Nairobi, Kenya. The group was formed to address the challenges facing young women and the girl child in Korogocho slum. The group has 20 members in total. (15 Female and 5 Male)

The challenges that the group seek to address are; poverty, prostitution, early pregnancies, early marriages, abortions, school dropout and crime among other problems.

These problems are majorly due to low level of income. The group seeks to address these challenges through economic empowerment to members and young women in the society.

This is done through various economic activities that the group is involved in. The activities that the group engages in so as to empower its members are: production of sandal, bags, bracelets, mats bead work and sanitary towels. The group is also involved in environmental conservation and community work like reproductive health programs in the local school.

We use ecological waste materials which contribute to pollution, in our production. Most of our raw materials include: (i) Old fabrics (Renin) (ii) Organic cotton (iii) Old tires

Contacts: TWAWEZA INITIATIVE, P.O BOX 7714-00300 NAIROBI. Email; twawezainitiative@gmail.com Tel: 0714356845/0706382359/0715188634/ 0739561662. www.twawezainitiative.com | Facebook: Twaweza Initiative | Twitter: Twaweza Initiative

KCB Bank LTD – Ruiru Branch

KCB Group is registered as a non-operating holding company which started operations as a licensed banking institution with effect from January 1, 2016. The holding company oversees KCB Kenya – incorporated with effect from January 1, 2016 – and all KCB's regional units in Uganda, Tanzania, Rwanda, Burundi, Ethiopia and South Sudan. It also owns KCB Insurance Agency, KCB Capital, KCB Foundation and all associate companies. KCB offers a wide range of products in agriculture including: KCB Dairy loans ; KCB Agribusiness Working Capital Loans; KCB Agribusiness Asset Finance Loans; KCB Horticulture product; KCB Kenya Seed product; KCB Mavuno product KCB Bio Digestor loan product.

Equity Bank ltd- Kenyatta University Branch

Equity Group Holdings Limited, formerly Equity Bank Limited, is a Kenya-based commercial bank. The Company provides financial services to individuals and small and medium sized enterprises. The Company operates in six geographical markets: Kenya, Uganda, South Sudan, Rwanda, Tanzania and Democratic Republic of Congo. Its three customer facing lines of businesses include consumer, small and medium enterprises (SME's) and corporate. The consumer business line focuses on salaried customers or customers receiving other regular remittances, such as pension. The facilities granted under its SME's line of business are for purposes of meeting working capital needs, property development or acquisition of assets. The corporate line of business comprises large enterprises. The Company offers a range of products, including Equity loan, Vijana loan, Fanikisha loan, Farm input, Mortgage loan, Asset finance loan, Trade finance, Development loan, Business Loan and Biashara Imara. Products in support of agriculture include: Kilimo biashara loan (small scale), Kilimi Biashara (Agribusiness), Kilimo Maendeleo Loan and Kilimo kisasa loan.

OSHO Chemical Industries Ltd

Osho Chemical Limited is a leading marketer, manufacturer and distributor of agricultural inputs, industrial chemicals and veterinary products. Its product range include: ***Agricultural Inputs*** – Agricultural chemicals, Bio-pesticides, Fertilizers, Knapsack sprayers, Greenhouse sheeting and Growth media. ***Industrial Products***: Industrial Chemicals, Industrial & Institutional Detergents, Oxides and Dyes, Screen-printing auxiliaries, Other Industrial inputs and equipment. ***Veterinary Products***: Dewormers, Acaricides, Mineral Supplements and Metabolic Stimulant, Trypanocidals, Antimirobials, Disinfectant and Antiseptic, Poultry Products, Cattle Sprayers, Toxorid, Bloatosil, Vaccine and Identification Equipments. In addition to this Osho undertakes third party Toll manufacturing.

Kenya Livestock Marketing Council

The Kenya Livestock Marketing Council (KLMC) is an umbrella organization of livestock producers and traders in arid and semi-arid areas of Kenya. It was established in 2000 as a non-profit making services organization to counter the challenges the livestock farmers are facing. KLMC is an non-political, non-religious/commercial livestock pastoralists organization and is an affiliate of KENAFF,AIN, KEPSA, Kenya Chamber of Commerce, joint Arab Chamber of Commerce and NEALCO.

KLMC believes that pastoralism is the key economic activity in the Arid and Semi-Arid areas of Kenya and it can be harnessed to promote economic growth and development in these regions and reduce vulnerabilities.

KLMC recognizes the fundamental challenge facing the pastoralists is their inability to access better market for their livestock and livestock products. In order to overcome this challenge, KLMC is working closely with other development partners and stakeholders to source for better market for livestock and livestock products and disseminate market information to producers and traders on timely basis within the country , regionally and internationally.

The National Sericulture Research Centre, Kenya Agricultural and Livestock Research Organization (KALRO)

The Kenya Agricultural and Livestock Research Organization (KALRO) is a premier national research organization established under the Kenya Agricultural and Livestock Research (KALR) Act No. 17 of 2013 as a successor of four former agricultural research institutions; Kenya Agricultural Research Institute (KARI), Tea Research Foundation (TRF), Coffee Research Foundation (CRF) and Kenya Sugar Research Foundation (KESREF). It is mandated to conduct agricultural research of strategic and national importance and produce public goods in the form of technologies, information and new knowledge. KALRO comprises of 16 interactive and interdependent network of semi-autonomous institutes (comprising of over 50 centres and sub centres) situated in different parts of the country each with specific mandates that contribute to the overall vision and mission of KALRO.

The National Sericulture Research Centre is one of the KARLO centers with a national mandate for promoting and catalysing growth of sericulture industry in Kenya. The center focuses on Developing business incubation and technology centre where entrepreneurs will receive apprenticeship to gain practical experience in the industry, Establishing strong business models for sericulture industry in Kenya; Building strong research outputs to support the industry, in collaboration with key partners and Establishing a national grainage for the silkworm seeds to cushion and protect domestic sericulture. The center is involved in the production and marketing of the following products: Raw silk, Mulberry cutting and saplings, Spunned floss, Silk and silk blended fabrics,Mulberry tea,Silkworm pupa for animal and poultry feed, dry cocoons and shells

For more information please visit: www.karlo.org

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

ICRISAT is an international non-profit organization that undertakes scientific research for development. It works in agricultural research for development across the drylands of Africa and Asia making farming profitable for smallholder farmers while reducing malnutrition and environmental degradation. ICRISAT works across the entire value chain - from developing new varieties to agri-business and linking farmers to markets. Because of its focus on the drylands, the organization has an extra specialization on crops that survive in these harsh climates. These are: Sorghum, Finger Millet, Pearl Millet, Chickpea, Pigeonpea and Groundnuts. ICRISAT has offices in Kenya, Malawi, Mali, Mozambique, Niger, Nigeria, Ethiopia, Zimbabwe and India. It is a member of the CGIAR System Organization.

For more information please visit: www.icrisat.org

Kenya Plant Health Inspectorate Services

Kenya Plant Health Inspectorate Service (KEPHIS) is the government parastatal whose responsibility is to assure the quality of agricultural inputs and produce to prevent adverse impact on the economy, the environment and human health.

Vision: The Lead Regulator and Facilitator of Globally Competitive Agriculture

Mission: To Provide a Science Based Regulatory Service by Assuring the Quality of Agricultural Inputs and Produce to Promote Food Security and Sustainable development

Strategic Objectives

- To protect plants from pests, weeds and invasive species.
- To facilitate review and strengthening of the policy, legal and regulatory framework, so that it is in tandem with both local and international agricultural sector emerging issues.
- To contribute towards improved levels of agricultural productivity.
- To support compliance to market requirements.
- To build adequate technical and infrastructural capacity to facilitate efficient and effective delivery of the KEPHIS mandate.
- To mobilize adequate financial resources and ensure optimal allocation and utilization to enable full implementation of planned programmers and activities.
- To enhance synergies through information and resource sharing with stakeholders and partners.

For more information visit: www.kephis.org

CONFERENCE FULL PAPERS

1. Plenary Session 2: Livestock Production and Health Issues

1.1 Analysis of consumer preferrence in product attributes: A case study of indigenous chicken' eggs in Kenya

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Abstract
Indigenous chicken eggs are highly preferred in Kenya by majority of both rural and urban consumers. In the recent past, research has focused on improving productivity levels resulting to Improved indigenous chicken eggs with less focus on consumer preferences. Despite their efforts, Indigenous chicken eggs dominate the market and the country is egg deficit. This study sought to identify and analyze preference attributes of indigenous chicken' eggs that influences choice and consumption. The specific objectives were to; identify and rank indigenous chickens' eggs attributes that influences choice and consumption and analyze the influence of these attributes on price of eggs. Multistage sampling technique was employed to select 180 respondents in Nairobi and Makueni counties. Kendall coefficient of concordance test was used to identify and rank the attributes of indigenous chicken' eggs while semi-logarithmic functional form of hedonic pricing model was employed to analyze the influence of eggs attributes on price. Results indicated that consumers buying indigenous chicken eggs prefer and are willing to pay premium prices for brown shelled, non oval eggs. Small and medium sized eggs were also more preferred and received price premiums compared to the larger sized eggs. Small and medium sized eggs were perceived to be organically produced with less chemical components. The study recommended for incorporation of this attributes by breeders. Farmers can enhance the preferred egg attributes by adopting better production systems while retailers can use the attributes in formulating appropriate marketing strategies in indigenous chicken eggs business.
Keywords: Attributes, choice, Hedonic pricing.

INTRODUCTION
Indigenous chickens(IC) contributes 71% of the total egg and poultry meat produced in Kenya and therefore impacts significantly on the rural trade, welfare and food security of smallholder farmers (Philip, 2007). Over 21 million people in rural areas depends on IC for livelihood support. Consumers exhibit high preferences for indigenous chicken

eggs and are willing to pay 41.53% more compared to other eggs (Bett et al., 2011). This preference is due to increasing knowledge on health complications associated with food consumption (Changhee, 2011). Today's consumers want an ever-widening variety of food products with various characteristics of nutrition convenience, food safety, environment and other traits. In general, changes in food consumption patterns are primarily as a result from increase in income and changes in food prices. As income increases, so is the demand for quality and safety particularly for food products. The new awareness is attributed to dietary changes associated with more disposable income and urban growth. For instance, in 2005, Kenya produced 60,000 tonnes of eggs in shells and imported 240 tonnes to fill the shortage in supply (FAO, 2008). The deficit is an indication of the local market failure to stimulate production. Production of indigenous chicken is characterized by low levels of inputs and outputs (Okitoi, 2007)with low productivity levels, which limits their potential for commercialization. This has resulted in development of improved indigenous chicken that have high productivity levels compared to IC. Emphasize on IIC eggs through high productivity levels has left out consumer preferences an important component in acceptability and marketing of products. Nonetheless, improved indigenous chickens' eggs have failed to fill the widening gap in demand for eggs and IC eggs dominate market share. There is therefore a knowledge gap on what consumers prefer in the IC eggs that is probably not in the recently released IIC eggs. Lack of consumer preference analysis could be a factor that limits utilization, subsequently low production of newly released IIC eggs. The problem therefore is insufficient information on the factors that determine choice of eggs by consumers in the market. The overall objective of this study is to fill this gap in knowledge. The paper will achieve this through its twofold objectives; to identify and rank attributes of indigenous chicken eggs that influence choice and consumption and to analyze the influence of these attributes on price of eggs. The results will inform and guide producers of improved indigenous chickens' eggs on the management practices and production systems to adopt in order to enhance attributes that fulfils market requirements hence increasing chicken' egg prices and demand. Consequently, traders will be able to adopt strategies in transportation, handling, storage and transformation in order to improve retail level chicken egg prices through emphasis on retail level attributes that are important to end users.

Several studies have applied hedonic pricing to disentangle preference attributes from bundled goods and their economic valuation. Egg types have different attributes which determine their attractiveness to consumers. These attributes are heterogeneous, making each type distinct. Hannah (2015), employed hedonic price model to analyze the effects of common beans attributes on price in Kiambu Kenya. Results indicated that consumers were willing to pay premium prices for taste, price and cooking time. Dalton (2003), used hedonic price model to evaluate consumption attributes perceived important by rice consumers in West Africa. Results showed that grain elongation and swelling were important in relation to the amount of rice prepared and the amount that can effectively feed a household. Timothy et al., (2006) sought to analyze cattle prices in central corridor of West Africa by employing hedonic price model. Specifically, the study was to determine if market participants have systemic preferences for cattle attributes and their willingness to pay premium price for the attributes. The results of the study indicated that animal age, sex, breed, body condition, purpose of purchase, season of sale and market location were the most significant factors influencing short run cattle prices in the study region. Ramatu et al. (2014) sought to determine the quality characteristics of dressed local and imported chicken that influence consumer preference and how these affect the prices of chicken. The study employed hedonic pricing model which indicated that consumers were willing to pay premiums for imported, non fatty and tender attributes of chicken. Changhee (2010) analyzed retail prices of eggs in Korea using hedonic price model in order to identify those attributes that affect prices and the respective value of each attribute. Results indicated that the status of eggs fertility, organic feeding and free range feeding are the main attributes that positively affect the retail price of eggs.

MATERIALS AND METHODS

Theoretical framework

Egg types have different attributes which determine their attractiveness to consumers while making purchase decision (Becker, 1965 and Lancaster, 1966). According to these theories, consumers choose indigenous chicken eggs that maximize their utility based on consumption characteristics. The underlying assumption postulates that products consist of utility-bearing attributes and that the values of those attributes collectively contribute to the price of the product (Rosen, 1974). This approach is called the hedonic pricing method in which the price of indigenous chicken egg is viewed as a composite of implicit values/prices of each individual attribute. The price of a good is a function of the amount of attributes that it contains and of the values placed on them (Carman, 1997). This can be represented as:-

$$P = \beta_0 + \sum_{j=1}^{m} \left(\beta_j Zj + \varepsilon\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(i)}$$

Where the vector Z stands for a particular variable of indigenous chicken egg, $\beta_0$is the intercept; β_j is the regression coefficient and ε is the random error term satisfying the classical regression assumption.

The study area and sampling

This study was conducted in Makueni and Nairobi counties of Kenya. Makueni county lies between latitude $1^0 35'$ South and longitude 37^0 10′ East (Makueni county integrated plan (CIDP), 2013). Nairobi county on the other hand lies between latitude 1^0 17′ south and longitude 36 ^{0} 49′ East and has nine sub counties. The target population for this study consisted of all consumers of indigenous chicken eggs in Nairobi and Makueni counties. Multistage sampling technique was used and 180 consumers selected in the four sub counties as follows; Kaiti 33, Makueni 57, Starehe 43 and Westlands 47 consumers.

Data Analysis

Hedonic pricing model was used to analyze the influence of attributes on price of eggs. The price is the dependent variable upon which egg attributes are regressed.

$$lnp_i = \alpha_0 + \sum_{n=1}^{k} \beta shell\ color + \sum_{n=1}^{k} \beta size + \sum_{n=1}^{k} \beta clean + \sum_{n=1}^{k} \beta shape + \sum_{n=1}^{k} \beta package + \sum_{n=1}^{k} \beta fresh + \sum_{n=1}^{k} \beta region + \sum_{n=1}^{k} SD + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

Where P is the price of IC egg in Kenya Shillings, SD represents socio-demographic factors influencing market price β_s are parameter estimates and ε is stochastic error term. Overall variables described above are dummy variables. In a semi logarithmic functional form (adopted for this study), the effect of a dummy variable on the dependant variable is not equal to the first derivative of the regression function with respect of the dummy variable in question, unlike the effect of a continuous variable (Kennedy, 1981). This implies that the first derivative (β) is a potentially imprecise approximation of the effect of the dummy variable on the dependent variable. Among the approaches available to correct this is the method suggested by (Kennedy 1981). Following this method, the effect of a change of x_k is from zero to one on P, can be calculated as follows (Kennedy, 1981).

$$g_k = exp\left(\beta_k - \frac{1}{2} V\ (\beta_K)\right) - 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(iii)$$

Where v(β_k) is the estimated variance of the estimated coefficient β_k

RESULTS AND DISCUSSION

Socioeconomic characteristics of the sampled households

Out of the sampled respondents in both counties,56% comprised of male while the rest were female as shown in table 2 implying that in Urban centres there is a large percentage of male as compared to women who in most cases are found in rural areas engaged in farming activities. This can be attributed to rural – urban migration in search of employment by majority of men(Table II). The mean age for the respondents was 36years (table II). The youngest respondent was aged 17 years and was a male while the oldest was aged 85 years and was a female. The literacy rate of 96.5% seemed to be higher in the study area compared to the national average literacy rate of 87.01% (World Bank, 2009). Majority of the respondents; 48% had secondary level of education, 18% had primary level of education, 14% had Diplomas and 12% had Degrees. The average family size for the current study was 4 members with a minimum of 1 and a maximum of 11 family members. Among the sampled respondents,72% were married while 27% were single. 35% of the respondents received a monthly income of upto Ksh. 10,000 (table II). Only 21% of the respondents earned a monthly income of above Ksh. 30,000.

Attributes of I.C Eggs

I.C eggs that were identified during the preliminary survey were presented to respondents for verification and ranking. The attributes were; shell color, size, shape, cleanliness, price, freshness and package. Results of Kendall's ranking indicated that size, price, shell color and freshness of the I.C eggs were the most important attributes influencing consumer choice and consumption. Cleanliness and Package of the IC eggs were the least ranked attributes influencing choice and consumption (Table III). The F-test results indicated that 36% of the respondents were in agreement on ranking of the IC eggs attributes at 99% confidence level. The null hypothesis was thus rejected and alternative which stated that there is significance agreement among respondents in ranking the IC eggs attributes adopted.

Influence of Indigenous Chicken Eggs' Attributes on price

For the indigenous chicken eggs, a total observation of 180 respondents was made. The estimation of semi-logarithmic form of equation was completed using the ordinary least squares method (OLS). The model included seventeen independent variables which were all dummies with the exception of age and household size of the respondent. Heteroskedasticity and multicollinearity is a problem associated with cross-sectional data, hence they were tested using Breusch-pagan test and variance inflation factor (VIF) respectively. A mean VIF was 1.79 and no variable individually had a VIF of above 5 (rule of thumb) for presence of multicollinearity. The hypothesis for homoskedasticity in error term was thus accepted ($P>0.10$).The significant effect of each independent variable on the price of eggs was tested with a t-statistic. The hypothesis of a coefficient not different from zero is rejected for one variable at $\alpha=0.01$, three variables at $\alpha=0.05$ and two variables at $\alpha = 0.10$. The remaining variables are found statistically insignificant. Insignificant coefficients of the variables suggested that consumers either do not have adequate information to incorporate the characteristics into their buying decisions or that they place no value on such attributes when they buy indigenous chicken eggs. The results of F-test (F=3.41significant at one percent) indicates that the independent variables as a set significantly affect the dependent variable(Price of I.C egg) .The R-square (0.26) indicates that 26% of the variability in I.C egg price is explained by the empirical model. Table IV shows estimates of coefficients, corresponding standard errors and marginal implicit prices. Marginal implicit prices are calculated by multiplying the average price with the relative change which is the corrected unbiased partial derivative of price with respect to each product attribute (Kennedy, 1981). The attributes are interpreted with respect to the default dummies (Gujaratti, 1995). White shell color is negatively related to price. *Ceteris paribus* a change in shell color from brown to white significantly ($P<0.05$) results in 8.1% decrease in price of indigenous chicken eggs. This indicates that compared to brown eggs, white eggs will attract price discounts of Ksh.1.4/egg. This is contrary to our expectation of price premium in favour of white shell. The study found that 78% of respondents preferred white eggs compared to 22% who had purchased brown shelled eggs. This implies that although consumers show preference for white shell, they are unable to value it while making purchase decision probably because of wide spread brown eggs. The estimated implicit price show a strong potential for developing niche markets for I.C eggs. This attribute was ranked third in importance by consumers while making their purchases. Cleanliness and freshness, though with an expected positive relationship to price, were not significant ($P>0.10$). There was no significance difference between prices of clean and non clean eggs and fresh and non fresh eggs. Further still during Kendall ranking of attributes' importance, the two attributes ranked least on the scale. This indicates the wide availability of fresh and clean eggs in the market to an extend that consumers do not make distinction between the two categories when valuing eggs. Shape of an I.C egg significantly ($P<0.10$) influenced the price of eggs. *Ceteris paribus* the price of an oval egg tends to be 7% (Ksh. 1.25/egg) less compared to that of a non oval egg. This premium price for non oval eggs could be attributed to other specific roles/purposes upon which such eggs are purchased (beautification, tourism or breeding) and the perception that they have more value than the ordinary oval eggs. Indeed, the study only found out that only 6% of consumers had purchased non oval eggs implying the scarcity nature of such eggs. This implies that breeders, producers and retailers can capitalize on this new emerging market by increasing such eggs in the market. As expected, eggs prices are found to be significantly influenced by the size. Small sized eggs were found to significantly ($P<0.10$) positively influence market price. *Ceteris paribus*, the price of a small sized egg tends to be 15% (Ksh. 2.76/egg) more than that of an extra large egg (default). Consequently, medium eggs significantly ($P<0.05$) influenced price and the price of a medium sized egg tends to be 9% (Ksh. 1.77/egg) more than that of an extra large egg ceteris-paribus. This study also found out that consumers bought 7%, 52%, 38% and 3%of small, medium, large and extra large eggs respectively. This implies the perception that small eggs are produced organically and hence more nutritious with minimal health related problems than large and extra large eggs which showed no significant difference in their prices. Producers and retailers should endeavour to fulfil this niche market by targeting it with small and medium sized eggs so as to fully maximize on returns. The study also found that size was the most ranked egg attribute in making the purchase decision. The price of eggs was also found to respond to other socio-economic attributes such as household size and region. The study found that large household paid a premium of 2.0% compared to small sized households indicating market imperfection. This was significant at ($P<0.01$). On the other hand, price of eggs varied significantly across sub counties, for instance the price of eggs in Westlands were 15% (Ksh.2.7/egg) higher ($P<0.5$) than the price of eggs in Kaiti. Consequently, consumers in Makueni and Starehe paid premium compared to those in Kaiti although this was not statistically significant. The price difference is due to differences in geographical locations and socio-economic status of the consumers in these regions.

TABLES

Table I: Explanatory Variables and the Priori expectations for the study

Dummy Variable	Categories	Priori Expectation
Shell color	White	+
	Brown	-
Freshness	Fresh	+
	Otherwise	-
Shape	Oval	+
	Otherwise	-
Size	(extra large)	-
	small	+
	medium	+
	large	+

Table II: Socio Economic Characteristics of the sampled households

Characteristic	%	MIN	MAX	MEAN	SD
Gender					
Male	57				
Female	43				
Age	__	17	85	36.09	12.89
Household size	__	1	11	4.1	2.35
Marital status					
-married	72.5				
-single	26.5				
-widow	0.5				
-divorced	0.5				
Monthly income					
<Ksh 10,000	35				
Ksh.10,000-20,000	28				
Ksh.20,000-30,000	16				
>ksh.30,000	21				

Table III: Kendall Ranking of the Indigenous Chicken' Eggs Attributes.

IC egg attribute	Rank	Sum of Ranks
Price	2	512.5
Size	1	502
Shell color	3	666.5
Cleanliness	6	829
Freshness	4	678.5
Shape	5	794
Package	7	917.5
N	175	
W	0.17	
F calculated	36.51	
F- Critical	2.10	
Significance	1%	

TableIV: Estimation of Hedonic Price Model for Indigenous Chicken' Eggs

Variable	Coefficient	Std error	Relative impact	Implicit price
Shellcolor(white)	-0.07920**	0.03230	0.0818	1.4
Freshness(fresh)	0.0446	0.0334	0.0450	0.8
Shape(oval)	-0.0687*	0.0389	0.0703	1.25
Cleanliness(clean)	0.01860	0.03648	0.01809	0.32
Size (extra large)	Default	-	-	-
small	0.1463*	0.0750	0.1542	2.76
medium	0.0954**	0.0459	0.0989	1.77
large	0.06409	0.0430	0.06529	1.16
Sub county (Kaiti)	Default	-	-	-
Westland	0.1423**	0.0584	0.1509	2.70
Starehe	0.02364	0.05361	0.0224	0.40
Makueni	0.0182	0.0482	0.0171	0.307
Gender (Male)	0.0392	0.03018	0.0395	0.70
Education	0.0050	0.0133	0.0049	0.88
Income	0.0121	0.01020	0.0121	0.21
Age	0.0000	0.0012	0	0
Marital status	-0.01043	0.0327	0.0099	0.17
House hold size	0.01936***	0.0058	0.0195	0.34
Constant	2.6271	0.1188		
F	3.41***			
R^2	0.2637			
Adjusted R^2	0.1864			
N	180			

CONCLUSION

This study aimed to establish consumer preference attributes in indigenous chickens' eggs. Hedonic pricing model was employed to analyze preference attributes and their influence on price in Makueni and Nairobi counties. Findings of the research have shown that shell colour, size and shape are important attributes influencing price and consumption of IC eggs. Furthermore, socio-demographic characteristics of the respondents such as household size and region (sub-county) influenced prices of indigenous chicken eggs confirming existence of market imperfection in the I.C market. The study made the following recommendation; first, Farmers in the study region and beyond should consider altering their feeding and management practices of indigenous chicken so as to influence incorporation of preference attributes in the IC eggs for sale through quality feeds and sound production systems. Second, researchers should incorporate attributes of choice based on consumer preferences in their breeding work to enhance acceptability of eggs in the market.

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1.2 Livestock Keepers in Isiolo County, Embrace New Adaptive Strategies as Mitigation Measures against the Effects of Drought

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ABSTRACT
Droughts are generally associated with the failure of the seasonal rains. The two major rainfall seasons in Kenya are the long-rains (March to May) and the short rains (October to December). Drought has become a perennial problem in Kenya with chronic vulnerability being concentrated in Arid and Semi-Arid lands (ASALs). Traditionally, pastoralists have used indigenous coping strategies to address these disasters, but recent studies have shown that the recurrence of droughts has weakened pastoralists' indigenous coping strategies. The overall objective of this study was to investigate the new adaptive strategies being used by livestock keepers of Isiolo against negative

effects of droughts. Household heads were interviewed with the help of a semi–structured questionnaire. Two focus group discussions were held and the participants of each group were men and women who were above 45 years of age. The trend of droughts and the effects of droughts on Borana livelihoods and new adaptive strategies applied. Quantitative data derived from the household interviews were edited, coded and analyzed using the Statistical Package for Social Sciences (SPSS) software version 20 spread sheets. Descriptive statistics were run to give frequencies and percentages. The study findings revealed that livestock keepers have adopted new coping strategies such as small crop production, camel rearing, small scale business and informal employment. According to the study findings the pastoralists have limited skills and capital to implement sustainable projects. This study therefore came up with two recommendations; the need for livestock keepers to be trained on appropriate skills on crop production and entrepreneurship. There is also need to link the livestock keepers to financial institutions who would give loans to livestock keepers to so that they can come up with sustainable business.
Key words: Droughts, coping strategies, pastoralists, livestock, Isiolo County

INTRODUCTION

Drought has become a perennial problem in Kenya with chronic vulnerability being concentrated in Arid and Semi-Arid lands (ASALs). According to KNBS (2010), ASALs account for 36% of the total population, around 14 million people. Droughts are associated with the failure of the seasonal rains. The two major rainfall seasons in Kenya are the long-rains (March to May) and the short rains (October to December). Natural disasters such as drought, floods, earth quakes and storms are not new to the arid and semi-arid areas. Traditionally, pastoralists have used indigenous coping strategies to address these disasters, but recent studies have shown that the recurrence of droughts has weakened pastoralists' indigenous coping strategies. Livestock production is the major economic activity in the ASALs of Northern Kenya. The communities living in these zones have been livestock keepers since time in memorial. However, the impact of drought, increasing insecurity, and famine has led to a growing emergence of sedentary livestock keepers and experimentation with alternative livelihoods. Over recent years, pastoral communities have had to employ other supportive activities to supplement pastoralism, which has proved to be ineffective in meeting all their economic and social needs (Watson and Van Binsbergen 2008). Golicha et al. (2012) work in Northern Kenya provides information on some of the alternatives livelihoods being adopted by the pastoralists in Marsabit County which includes crop farming, apiculture, casual work, small scale businesses formal employment, weaving, crafting and sand harvesting among others. There was inadequate information about the alternative adaptive strategies applied by the Borana of Isiolo in their response to the effects of droughts. As a result, this study was initiated whose overall objective was to investigate the new adaptive strategies being used by livestock keepers of Isiolo to cushion themselves against the negative impact of droughts. The study was guided by two objectives;

Specific Objectives

To examine the effects of droughts on the Borana pastoralists livelihoods

To establish the type of adaptive strategies which are being used by the Borana community of Isiolo County

MATERIALS AND METHODS

Study site and unit of analysis

This study took place in Isiolo Central which is a sub -County of Isiolo County situated in northern Kenya. The study focused only on the Borana community, although there other communities because it is the largest community in the County. This being the case the study was concentrated in the areas occupied by the Borana Community. The unit of analysis was the individual man and woman household.

Sample size and sampling procedure

This study applied both random and non-random sampling strategies. In selecting the study site simple random sampling technique was applied whereby the names of the three Isiolo sub-counties were written on pieces of paper which were folded several times. The pieces of paper were then put in a container which was shaken before the researcher picked one of them. This happened to be Isiolo Central. Three villages were selected purposively with the help of the local provincial administration who assisted to researcher to identify the three villages which were occupied by the Borana community. To get a representative sample size this study used a formula used by Mugenda and Mugenda (1999: 43-44). The accessible population in this study was 4000 households.

$$nf = \frac{n}{1 + \frac{n}{N}}$$

to be used to calculate samples size.Using the above formula sample size is:

$$nf = \frac{384}{1 + \frac{384}{4000}} = 350$$

To cater for those households that would decline to participate or drop out during the process of investigation, the study proposed a sample size of 400.

Systematic sampling was applied to select households for the interview. The sampling interval was determined by the equation given below.

$$Sampling\ interval = \frac{n}{N}$$

Where:

n= required sample size

N=Population size

n=400

N=4000

$Sampling\ interval = \frac{400}{4000}$=$\frac{1}{10}$(i.e., 1 in 10)

Data collection methods

Household interviews

Household interviews were conducted with household heads, male or female, through the administration of a questionnaire to the respondents. The interviews were conducted in Borana local language by enumerators who were from the community. The questions answered by household heads how their livelihoods have been affected by droughts and new adaptive strategies of pastoral communities.

Focus group discussions

Two focus group discussions were conducted and each group had 10 participants who were selected purposively. Each group had men and women who were above 45 years of age. The issues discussed included the effects of droughts on the Borana community livelihoods and their new adaptive strategies.

Data processing and analysis

Data obtained from focus group discussions were sorted out and interpreted in relation to the research general objective, to enable the researcher to provide overall interpretation of the findings showing how thematic areas and issues relate to one another. On the other hand, quantitative data derived from the household interviews were edited, coded and analysed using the Statistical Package for Social Sciences (SPSS) software version 20 spread sheets. Descriptive statistics were run to give frequencies and percentages.

RESEARCH FINDINGS

Effects droughts on the livelihoods of the Borana community

The study findings indicate that droughts have affected the livelihood of the Borana pastoralists to a great extent. The respondents said that their wellbeing has been affected in three ways as shown in Figure 1.

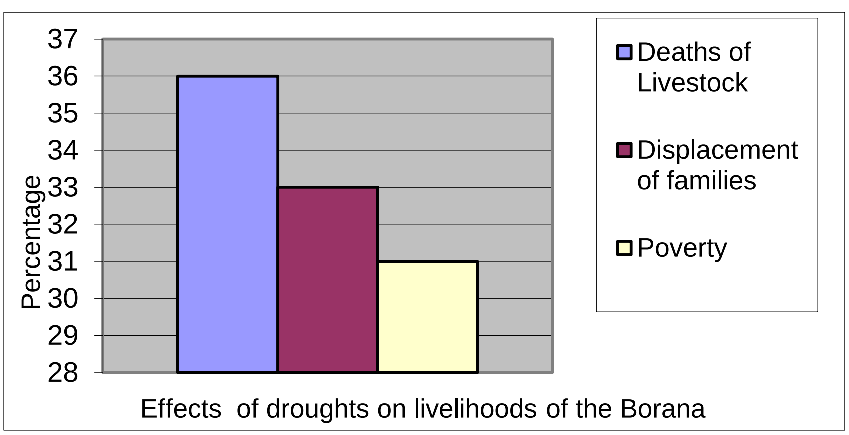

Figure **1: Effects of droughts on livelihoods of the Borana**

Thirty-six per cent of the respondents stated that severe and prolonged droughts had contributed to the death of livestock, which is the major economic activity of the community. Droughts had caused fluctuations in the livestock population through increased mortality and reduced birth rates due to decreased forage and water availability. Thirty-three per cent of the respondents stated that droughts had caused displacements as people moved with their livestock in search of water and pasture for many months leaving women, the elderly and children behind. In some cases this causes family breakdowns since some of the women engage in immorality so as to get finances to feed the remaining family members. Lastly, 31% of the respondents stated that poverty had become rampant in the Borana community. This argument was supported by focus group discussants who said that massive losses of livestock drove off large numbers of pastoralists from the pastoral system, which was their major source of livelihood.

Effects of droughts on the environment

The findings of this study reveals that droughts had affected the natural resources used by the Borana to feed their livestock (Figure 2). This is because half (50%) of the respondents said that trees and grass had dried up, 30% stated that rivers and water pans had dried up, while 20% said that desertification had increased.

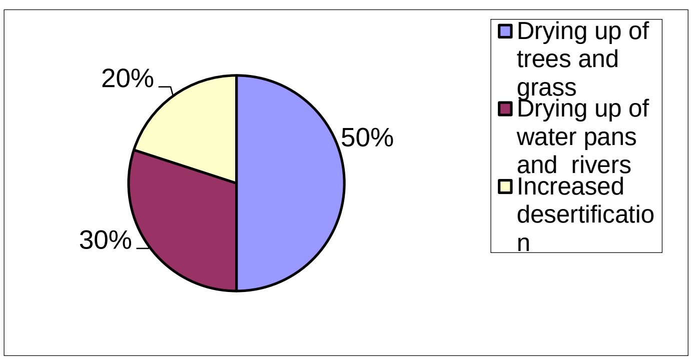

Figure 2: Observed effects of climate variability on environment

New Adaptive Strategies

The study findings suggest that climate variability has made the Borana community to diversify their livelihoods. Focus group participants stated that traditionally pastoralism was a full-time occupation and everyone from an early age was engaged. However, frequent and prolonged droughts had made the community to look for alternative ways of getting income. According to the results of this study, 33.3% of the respondents stated that they engaged in causal labour, 30.3% have turned to small-scale farming, while 24% engaged in small-scale business. Lastly, 12.5% of the respondents indicated that people had joined salaried employment. Figure 2 summarises the alternative livelihoods of the respondents.

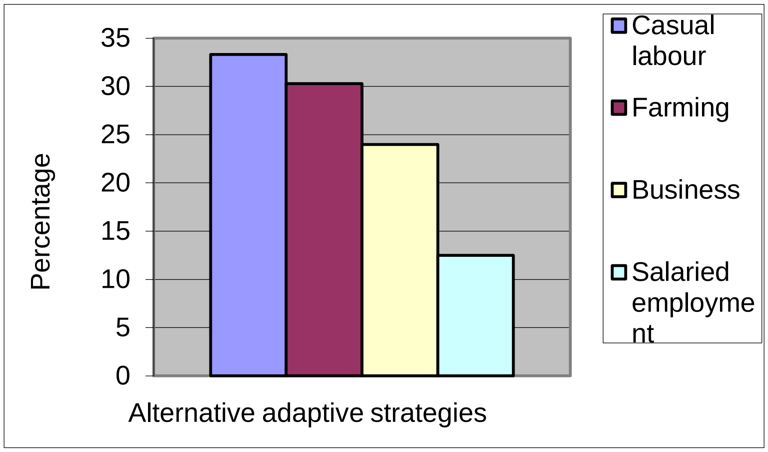

Figure 3: Alternative adaptive strategies of the respondents

This study indicates that even though livestock keeping was the most preferred source of livelihood among these pastoralists, there was increasing income diversification in the community particularly as an immediate survival mechanism during and after drought periods. Focus group discussants stated that many pastoralists are exiting from the traditional 'highly mobile' form of nomadism and entering into agro-pastoralism or sedentarisation and other livelihood options. According to Oxfam GB (2010:17) some households send members of the family as labourers to towns or other regions, or even abroad (usually to Middle Eastern countries) to work and send remittances for household use. More and more households send children to school in the hope of improving their access to employment in the future, while other households move and settle close to food distribution centres to secure better access to food.

Shifting of livestock preference from Cattle to camel rearing

Respondents were asked about the most preferred livestock species in the region. A majority (71.5%) of them said that they preferred camels. The reason they gave for this was that camels are most suited for the region as they can stay for many days without water and food. This is in agreement with Field (2005:93) who states that camels are the best suited in the ASALs due to their biological and physiological adaptations, which help them to cope with the hot and arid environments. In addition, they have varied diets which include shrubs and their height allows them to browse tall trees. Focus group participants were in agreement that drought had affected the range vegetation and this had impacted on the herd composition of the Borana. According to them:

In the last 50 years we used to have good grasslands and forages. This enabled us to have different livestock species. Today our range lands that were once covered with good grass-land have been replaced with unpalatable hardy and woody species. A change in vegetation composition from grass land to woody and unpalatable plant species, has forced pastoralists to *alter their livestock composition from grazing to browsing species, that is, from cattle and sheep to goats and camels.* **(FGD participants)**

Field (2005:100) estimated that the volume of milk produced by camels is six times that produced by indigenous cattle found in the ASALs. In addition, the milk is believed to have medicinal value, helping in the management of high blood pressure and diabetes in human beings (Ngeiywa et al., 2012:20). Focus groups discussants revealed that even the clans among the Borana, namely, *Karaiu Mbere* and *Aswa,* who used to consider camel rearing and utilizing camel products as a taboo have started rearing them and using camel products.

However, 22.3% of the respondents said that they would prefer goats and sheep because they give birth twice per year and sometimes give birth to twins. Focus group discussants indicated that small ruminants were easy and cheap to restock after a disaster. This argument concurs with that in Spore Magazine (2008:14) which states that livestock keepers have started rearing small ruminants as a mitigation measure against climate change. Those who were in favour of small ruminants indicated that they applied the zero-grazing system of production, whereby the owners were not required to go to insecure grazing areas. In addition, goats were considered to cause difficulty to livestock raiders as they disperse when approached. On the other hand, 4.5% of the respondents said that they preferred rearing cattle and the reason they gave for this was that when they sell cattle they get higher incomes as compared to other livestock. In the past, the Borana community was attached to cattle; they used to claim that they are the "owners of cattle". Traditionally, any person in the Borana community who never owned cattle was considered to be very poor and such a person was loaned cows by relatives so as to build a herd. The research findings suggest that the trend has changed and even development agents like Arid Lands gave camels to pastoralists as a restocking strategy. Finally, 1.5% of the respondents indicated that they had engaged in poultry production as these are never stolen by raiders.

CONCLUSION AND RECOMMENDATIONS

The finding of this study have revealed that drought has a great impact on the Borana livelihoods. As a result of this the community has engaged itself in new adaptive strategies which included causal labor, formal employment, small scale farming and business. However, it came out clearly that the alternative adaptive strategies the Borana community is engaged in are short-lived and not sustainable since the community has limited skills and capital to enable it have better gains.

This study therefore came up with two recommendations; the need for livestock keepers to be trained on appropriate skills on crop production and entrepreneurship. There is also need to link the livestock keepers to financial institutions which would give loans to livestock keepers so that they can come up with sustainable initiatives.

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1.3 Milk production in Kenya: Challenges and opportunities

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Abstract

Dairying in Kenya is characterized by small scale and labour intensive operations such as hand milking. The aims of this research were to determine trends in milking by hand, by milking machines and technology needed for dairying. The research used an interview schedule and convenience sampling method in Naivasha, Nakuru, Eldoret, Kitale, Nyandarua and Nairobi regions. A total of 74 farmers milking by hand, 8 farmers using milking machines, 50 experts in Kenyan dairy sector, 5 dairy processors and 9 dairy equipment dealers were surveyed. The results indicated that the breeds reared were either pure or crosses of Friesian (56%), Aryshire (30%), Jersey (7) and others 7%. The difference in breeds reared by farmers milking by hand and machine was not significantly different (P<1). About 9.7% had adopted milking machines and skilled hand milking personnel were 13%. The duration of milking by hand was mostly (62%) above recommended time (seven minutes). Majority of farmers (95%) and 96% of experts recommended adoption of milking machines for high milk quality, improved production and health of animal throughout lactation periods. The reasons farmers were not using milking machines were the cost, few herd and electricity. Farmers who milked by hand and supplied milk to dairy processors were 42%, of this, 37% had their

milk rejected for failure to meet quality standards. Each of sampled dairy processors received 60%-70% of milk processing capacity per day. Adoption of milking machines has been prevented by high initial and operation costs, lack of designs applicable for farms with less than 20 cows, sensitization and diversified marketing. The ones using milking machines are challenged with inadequate water and electricity.
Key Words: Hand Milking, Machine Milking, Challenges, Technology needs

INTRODUCTION

Background of the problem

Kenya produces over 3 billion litres of milk per year, 70% of which is from dairy cattle. Total milking herd is approximately 27.7 millions of animals (FAO, 2011). Milk production is mainly from cattle, camels and goats. Smallholder farmers dominate dairy production (80%), with limited land and small dairy herds (Majiwa *et al*., 2012). Milking is one of the major and final operations that determine profitability of a dairy farm. However, farmers are faced with several challenges that include low productivity, poor hygiene and hand milking routines. Hand milking exposes dairy animals to injury, dangers of disease transmission and incomplete emptying of the udder which complicate the health of the cow as well as subsequent milk yield (Dzidic, 2004; Millogo, 2010). Hand milking is slow, very tiresome and unhygienic. It is difficult for milkers to milk each cow within seven minutes. These challenges can be mitigated by investing in machine milking. The cost of farm machinery is high and/or not suitable for small scale farms which have minimized mechanization, hindering maximum yield.

The models of milking machines imported into Kenyan market; majority of small scale farmers cannot afford to buy and use. They require high initial capital and huge investment in electricity supply. Secondly, the design specifications for milking machines may be based on requirements of dairy industry of Countries of origin which would vary with Kenyan dairy industry requirements. Factors such as type/breed of dairy cattle reared, milk production per cow and average number of dairy cattle per farmer influence design specifications.

The research was conducted in some Kenya's dairy hub (Naivasha, Nakuru, Eldoret, Kitale, Nyandarua and Nairobi) that established local dairy trends. The aims were: to assess current usage and demand of milking machines, determine type and average number of cattle reared per farmer, challenges faced by farmers milking by hand and by a machines and obtain measures required to be undertaken to improve Kenyan dairy sector.

MATERIALS AND METHODS

Research Methods

A stratification was done into six regions; Naivasha, Nakuru, Eldoret, Kitale, Nyandarua and Nairobi. Figure 1 shows a section of Kenya map where the survey was done. A further classification of respondents was done into farms milking by hand, farms using milking machines, experts, dairy processors and dairy equipment/machines dealers. Fifteen samples of farms doing hand milking were chosen from each region except Nairobi. Due to low adoption of machine milking, uniform sample size per region was unattainable. Four farms machine milking were surveyed in Nakuru and two in Naivasha. In Nyandarua, Eldoret and Kitale one sample was surveyed in each region.

Experts were drawn from Dairy Training Institutes, dairy processing industries/Equipment dealers and Research and Development institutes. The minimum qualification was a Bachelors degree and in a position of a lecturer, supervisor or researcher in dairy sector. They were interviewed at their respective place of work. Six dairy equipment/machine dealers were from Nairobi and three from Nakuru. The dealers would not be found in other regions. Two dairy processors were sampled in Nakuru and Nyandarua, one was from Naivasha. No processor was assessed in Eldoret, Nairobi and Kitale.

A convenience sampling method was used to reach respondents. The survey was done from January to March 2015. It involved observation on milk production systems, interviewing and filling questionnaires that had been pretested. The data was analyzed using SPSS version 22 and Excel 2007 Microsoft programme. The analysis was mostly descriptive.

RESULTS AND DISCUSSIONS

A total of one hundred and forty six samples were obtained, seventy four were farms milking by hand, fifty experts, eight farms using milking machines, nine dairy equipment/machines dealers and the remaining five were dairy processing plants.

Trends in milk production and management

The study showed that majority (54%) of farmers milking by hand had a dairy herd of 1 to 10 cows (mean of 6). About 27% had a herd of 25 – 58 cows. Table I shows number of cows owned by farmers milking by hand. The breeds were either pure or crosses of Friesian (56%), followed by Aryshire (30%), Jersey (7%) others were 7%. Friesian cows dominated small holder farms in Western Kenya (Omondi *et al.,* 2014) which agrees with this research. Majority of milking people were Semi killed 58%, unskilled 29% and skilled 13% (had training). About 60.5% of farms hired milking people. Unfortunately, most milking personnel highlighted that they were not happy with milking routine work. This was noted as the rate of hiring was temporary and frequent workers' exit. About 39.5% farms used family members as milkers. If different people milk, clear milking routine instructions and training are necessary for quality milk production (Ruegg, *et al*., 2005).

The farms using milking machines were 9.7%; the ones who used herringborn (Parlour system) milking machines had a herd of 400-800 (37.5%) and 100-400 (50%). About 12.5% had herd of around 25 -40 cows and had adopted bucket milking machines. Table II shows total herd owned and milked by farmers using milking machines. In about 62.5% of farms machine milking, milking herds were below 50% of the total herd. The mean of milked herd to total herd was 51%, a higher rate than one indicated by Kenya Dairy Board (32.3%) survey of 2013. The means of Kenya dairy board was based on farmers milking by hand and those using milking machines (all dairy farmers) which might have pulled the mean down. The mean of this study (51%) is based on farmers using milking machines. This indicates that, embracing technology in farms increases productivity. The breeds reared by farmers using milking machine were; Friesian which accounted to 56%, Aryshire 32%, Jersey at 7% and other breeds were 5%. The difference in breeds reared by hand milking and machine milking farmers were not significantly different ($P<1$).

The time spent in milking each cow is very important in ensuring that maximum milk yield is attained throughout the lactation periods. The time of milking each cow by hand is a function of milk yield per cow and skill of a milking person. Seven minutes is the recommended maximum. However 62 % of farmers milking by hand exceeded this time with a number of them going up to twenty minutes. It was encouraging to note that some farmers had information that they should milk within seven minutes. The duration of milking by a machine is a function of milk yield of a cow and pulsation rate of a machine. All farmers who used milking machines were within the recommended time (seven minutes), most of them (63%) attained five minute and below. Day to day milk variation of machine milked cows is 6-8% while a hand milked and restrictedly suckled cow is high, 18 -21% (Millogo, 2010). There is 5.5% increase in milk yield in standardized milking procedure compared to a variable milking procedure (Ruegg *et al.,* 2005). The procedure may, among other factors be influenced by level of motivation or stress of a milking person ,which varies from day to day and caused by many factors surrounding a person unlike a milking machine.

Hand milking farmers who supplied milk to processing plants were 42%, while 47.3% sold direct to consumers such as hotels, institutions, shops and neighbors. A 10.7% did not sell their milk. Those who supplied milk to a processing plant, 37% indicated that the milk would often be rejected because of failure to meet quality standards. Quality assurance managers highlighted that the rate of rejection was high to milk from hand milking farmers and to that supplied by brokers. These was attributed to milking procedures and dirty milking parlors that are muddy during rainy season which increases contamination between milking person and milk. Brokers' urge of making more money, skim or neutralize milk which causes rejection. Farmers shy from supplying milk to processing plants due to low prices offered by the plants. Another reason was fear of rejection and therefore, sell direct to consumers who are not able to analyze its quality before use.

Milk is contaminated immediately after milking with bacteria and the level of contamination becomes harmful when milk reaches a consumer (Millogo, 2010). Many small scale farmers in Romania were hand milking, had no milk storage tanks to store milk at right temperatures and used dirty milking parlours (Popescu, 2015), depicting unhygiene conditions where milk is produced. Their milk was often rejected by milk processors for failure to meet European Union standards; which agrees with findings of this study. Consumers must be careful in consuming milk that is direct from farmers or has not been processed.

Challenges and opportunities in milk production

A 95% of farmers milking by hand indicated that they would like to use milking machines, while 2.5% said that they do not want a machine and the remaining 2.5% were undecided. Farmers highlighted various challenges (Table III) that have prevented them from using milking machines.

The farms that were hand milking and connected to electricity from national grid were 55%, 32.4% were connected to three phase while 22.6% had single phase. The ones not connected to electricity accounted to 45%. This agrees with factors in table III; that major reason why farmers are not using milking machines is not access to electricity, but the cost involved and herd size. Table I indicates that about 27% of farms have 25-58 dairy cows and some were connected to electricity but, were hand milking yet there are milking machines in the market for such a capacity. This has to do with the cost involved and lack of awareness of existence and importance of using milking machines.

The use of milking machines in Kenya dates back to 1970s. KALRO Naivasha (Dairy Research Institute) was the oldest in the samples with over 40 years of operation. Herringbone (8 aside) milking machine was installed in the institute in 1970s and was still in operation. Other farms had improved from bucket type of milking machines to Herringbone due to need of quality and zero contact of human beings with milk. About 50% of farms had used milking machines for more than 10 years, an indication of reliability. Majority, 63% highlighted that they faced challenges in using milking machines that included blackouts or low voltages, parts breakages, low pressures and resistance of the cow when introduced to a machine for the first time.

The farms using milking machines that were connected to electricity from national grid and had a standby generator were 62.5%. While 37.5% depended only on electricity from national grid and reverted to hand milking in case there was no electricity. The abrupt revert from machine milking to hand milking creates variation (Johnson, 2000). It would be good if all farmers would have power back up. A dairy farm can generate its own electricity that can be derived from biogas and/or solar. Unfortunately, most farms had not ventured into these technologies for their dairy production.

Cleaning a parlor (herring borne) milking machine requires an approximate of 600 to 1200 litres of water after every milking. In some of milking parlours, it was evident that the cleaning process was not followed as per requirements of manufacturer. Some measuring cylinders had stained due to poor cleaning. Some farmers used different detergents from ones recommended and were inaccessible to enough water. A bucket type of milking machine requires an approximate of 20 – 30 litres of water for cleaning. Hand milking requires about 5-8 litres of water. It might require farms to have more access to water and electricity if they adopt milking machines. These are some of operation costs that hinder farms from using milking machines.

Views from Experts in Kenyan Dairy Sector Concerning Milk Production

The experts interviewed were Animal scientists, Veterinary doctors, Engineers, Dairy technologist and/or farm managers. They gave their views as indicated below.

A 96.3% of respondents recommended farmers to use milking machines by giving the following reasons; efficient milking with complete emptying of udder within seven minutes, high milk quality, and low chances of mastitis. Does not require skilled hand milking personnel, accuracy in recording and monitoring milk yields per cow, consistency, reduce theft of milk and reduce milk rejection at selling points. The other, 3.7% failed to recommend the use of milking machines citing that it is expensive to buy, install and operate, some animals are stressed up and teats block or die.

The expert's opinion on efficient milking with complete emptying of udder within the required time (seven minutes) agrees with the findings of the author's survey with farmers using milking machines, most of them attained five minutes and below. High quality milk from farmers using milking machine is true as their milk was not rejected by milk processors. Milk from hand milking farmers was often rejected. There is high somatic cell count which influence milk quality in smallholder dairy farms milking by hand (Vo Lam, 2011). The high somatic cell count is as a result of poor udder health. Careless milking hygiene causes subclinical mastitis at cow and herd levels. There is high chances of controlling mastitis by machine milking than hand milking (Graeme, 2012) which agrees with experts' opinion. Milking machine is unlikely to cause mastitis and harm on a farm if it is installed, operated, maintained, tested and functions according to standards (Laven, 2016). Herring borne milking machine is designed with a measuring cylinder which records milk yield per cow. The system pumps milk to a milk cooling storage tank that can be locked minimizing milk theft.

The experts were asked about the measures that have been put in place to encourage farmers to use milking machines. About 22.3% indicated that there have been exhibitions and demonstrations by machine dealers and extension officers during farm fields and shows. In addition, commercial banks advance loans for purchase of milking machines. Majority of experts (77.7%) felt that no measures had been put in place to encourage farmers to use milking machines. About 4.4% of farmers milking by hand indicated that they do not know the importance of using milking machines, 2.2% were not aware that milking machines exists . This calls for more sensitization on existence and importance of using milking machines.

When asked about the measures to be undertake to improve dairy production, the experts recommended that a public organization to work with farmers to design and develop milking machines affordable and applicable to small scale farmers. Increase in supply and reliability of water and electricity should be increased. Adequate water intake increases milk yield (Vo Lam, 2011), increasing water to farms should be a major undertaking. The government should lower prices or partner with donors in promoting the use of milking machines. In addition, the experts suggested a proper civic education in advantages of mechanization and reduction in the cost of farm machinery and spare parts. County governments were urged to invest in milk cooling plants in dairy hubs.

Milk marketing was noted by experts as one of the challenges facing dairy sector. They felt that an improvement is required in marketing channels, infrastructures, milk pricing and guidelines to reduce exploitation by middlemen. Development of improved marketing systems is a gateway to increased production (Kedija, 2007). Animal production attributes such as an introduction of high yield and quality genetics, training on pasture and fodder production technologies were recommended. Better ways of feeding, breeding, health and policies that encourage animal production and processing were emphasized as well. Promotion of research to solve local problems was additionally suggested by experts.

Dairy Processing Industries and Equipment/Machine dealers

The milk processing industries surveyed received about 60% - 70% of their milking processing capacity per day. The volumes rejected were 6,000 – 7,000 litres per day. Milk was received from brokers, individual farmers or processor's own cooling plants. On delivery, milk was checked for fat and protein percentages, acidity, density, total pathogenic germs and somatic cell counts. The standard fat is 3.5%, number of pathogenic germs is a maximum of 100,000 per ml of milk and total somatic count is a maximum of 400,000 per ml of milk. The parameters reflect where milk was produced and the degree of disinfection used (Popescu, 2015). The parameters determined the rejection or acceptance of milk.

Industries are supposed to run throughout to conserve energy. Due to in ability to receive 100% of their capacity per day, short shut down happens which are costly to the industry. The extra energy cost incurred has a high probability of transfer to a consumer. Some farmers were not supplying milk to dairy industries because of low prices offered by industries. Proper milk pricing motivates farmers to improve production. This requires industries to review prices or inputs they give to farmers in order to encourage farmers to supply milk to them.

Kenya imports milking machines majorly from Sweden, Turkey and China. The classes of these machines are; bucket, trolley (single or double) and Parlors (Herringborn). Stock turnovers of milking machines were low. Out of nine dairy equipment dealers surveyed; only three had stocked milking machines. The dealers were concentrated in Nairobi, the capital city, forcing farmers to travel long distances for purchase of machines/Equipment and spare parts.

TABLES

Table I: Dairy cows owned by farmers milking by hand

Dairy Cows	Frequency	Percentages		
50 -60	10	13.5		This category can use bucket milking machines
40-49	4	5.4	27%	
25 -39	6	8.2		
15-24	10	13.5		This category may find it uneconomical to use any current designs of milking machines
10-14	10	13.5	73%	
5-9	16	21.6		
1-4	18	24.3		
Total	**74**	**100**		

Source: Author's calculations

Table II: Total Dairy Cows and Milked Cows for farmers using milking machines

Total Dairy cows	Milked cows	Percentage Milked
162	48	30
325	140	43
320	144	45
150	58	39
40	25	63
450	220	49
473	320	68
800	600	75

Source: Author's calculations

Table III: Factors that have prevented farmers from using milking machines

No	Factors Preventing the use of milking machines	Percentage of farmers
1	It is costly to buy, install and operate	53.3
2	Have few cows	20.2
3	Have no access to electricity	11.1
4	Have no knowledge of the importance of using milking machines	4.4
5	Low milk yields	4.4
6	Lack of appropriate farm structures	4.4
7	Not aware that milking machines exist	2.2

Source: Author's calculation

CONCLUSIONS

Milk production is dominated by smallholder farmers; about 73% own less than 25 dairy cows and around 46% own less than 10 cows. The adoption of milking machines is in farms with a milking herd of 25-600 and total herd of 40-800 cows. Majority (95%) of farmers milking by hand and 96% of experts would like or suggested adoption of milking machines for high milk quality, improved production and health of animal throughout lactation periods. Lack of adoption of milking machines by majority of farmers has been prevented by high initial and operation costs, lack of design applicable for farmers milking less than 20 cows. Lack of sensitization and diversified marketing has also hindered adoption of milking machines. The ones using milking machines are faced with a lack of enough water and electricity.

Farmers milking by hand are usually unable to get regular/skilled milking people, their milk fail to meet European Union or local standards and lack guidelines on milk selling prices. To improve dairy production, experts' feels that the government needs to promote mechanization, improve animal genetics, health, feeds, research, marketing and processing of dairy products.

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1.4 Infectious Bovine Keratoconjuctivitis (Pinkeye) Infection in a Dairy Cattle Herd in Kenya

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ABSTRACT

Infectious bovine keratoconjuctivitis (IBK) or Pinkeye is a highly contagious, non fatal eye disease of cattle worldwide but has marked economic impact due to production losses, rapid spread of the disease in a herd and treatment costs. A cross sectional study was done to determine the causes of pink eye infections in Ilulla dairy farm in Eldoret of Uasin Gishu County, Kenya from November 2015 to February 2016. Any cattle that showed signs of eye disease (lacrimation, photophobia and corneal opacity) were recruited for this study. A total of thirty heads of cattle that were positive on clinical examination of the affected eyes, were restrained in a crash and conjunctiva swabs were collected for bacteriological evaluation. Bacterial cultures were grown on blood agar media and colonial morphology recorded. Bacteria were identified after staining bacterial smears with Gram's stain. Antibiotic sensitivity tests were done for positive colonies. *Moraxella bovis,* a gram negative short rod which occurred in pairs or singly was confirmed in 33% of the ocular infections, other bacteria isolated included *Staphylococcal aureus* at 67% and Escherichia coli at 7% of the infections. Majority of the Moraxella infections were observed in calves 4 out of 8 (50%) and heifers 5 out of 14 (35.7%) while only 1 out of eight (12.5%) adults were infected. The infections were

observed in Friseans, Ayrshires and Guernseys. The bacteria were sensitive to wide range of antibiotics tested but were resistant to sulphamethoxazole. Some of the risk factors observed include was high density of face flies, feeding of dry dusty hay and the long dry spell during the time of the study. The infected animals were treated using Ampliclox® and measures to control flies around the milking parlour were instituted.
Key words: Keratoconjuctivitis, pink eye, dairy cattle, treatment

INTRODUCTION

Infectious bovine keratoconjuctivitis (IBK) or Pinkeye is a highly contagious, non fatal eye disease of cattle worldwide but has marked economic impact on the cattle industry. Ocular infections in cattle are usually acute and tend to spread rapidly. Pinkeye in cattle easily costs producers an average of $100 a head due to reduced weight gain, added treatment costs and discounts on sale day. University research has shown that pinkeye can reduce weaning weights in calves as much as 40 to 60 pounds (AG0066, 1998).

Morexiella bovis (*M. bovis)* is the primary infectious agent initiating pinkeye. Other microorganisms initiating pinkeye include *Chlamydia*, *Mycoplasma*, and *Acholeplasma*, or viruses such as the Infectious bovine rhinotracheitis virus (IBRV), which can either add to the severity of the disease process or may serve as predisposing factors permitting a secondary infection with *M. bovis* (Ref). Other predisposing factors are excessive ultraviolet light (sunlight), the face fly (*Musca autumnalis*), the housefly (*Musca domestica*), the stable fly (*Stomoxys calcitrans*), plant material, and dust (Smith, 2002). Ultraviolet (UV) light is especially a problem for cattle lacking pigmentation around the eye. Lack of pigmentation allows increased UV radiation to sensitize the eye, resulting in inflammation and subsequent infection (Radostits *et al*. 2000).

Most of the ocular infections are transmitted by flies, commonly the face fly (*Musca autumnalis*) but also by the housefly (*Musca domestica*), stable fly (*Stomoxys calcitrans*) and *Arcyophora longivalvis*, a moth that feeds on the ocular secretions of cattle (Carter *et al.,* 1995). The disease is seen in both young and the adult animals. However, it is more common in beef breeds and is aggravated by grazing in tall grass, by a dry dusty environment and by the presence of the insect vectors (Carter *et al.,* 1995). Young animals are affected frequently with one or both eyes affected (Radostits *et al*, 2000).

Several studies have shown that the economic impact of ocular infections can be significant due to decreased weight gain in young animals, reduced milk yield, cost of treatments and labor decreased value of calves as a result of disfigurement of the eyes and losses in slaughter cattle (Smith, 2002).

Disease outbreaks are common during the dry season due to presence of dust and other mechanical irritants. Other predisposing factors for the disease are; prolonged exposure to sunlight (ultra violet rays), concurrent infections, vitamin A deficiency and breed susceptibility has also been reported with *Bos indicus* being least susceptible (Coetzer and Tustin, 2004). Animals having pigmented skin around the eye are more resistant to infection (Coetzer and Tustin, 2004). Young animals are affected frequently with one or both eyes affected (Radostits *et al*, 2000).

Previously before this study, the herdsmen at Illula farm had reported an increase in the number of ocular infections, treated them with cloxacillin eye ointments and tetracycline powder with some success but resurge infections occurred at the onset of the drier period.

MATERIALS AND METHODS

Area of study

This study was done at Illula dairy farm, which is a privately owned farm, in the outskirts of Eldoret town, Uasin Gishu County, Kenya. The farm lies at the coordinated of $0^{0}31^{1}$N, $35^{0}16$ E. It is in the highlands of Kenya at an altitude of 2073 M, average temperatures of low 16.9 ^{0}C and high of 23 ^{0}C. The area receives rainfall throughout the year with annual rainfall of 1100mm, peak months being April/ May and July/ August. The drier months with low rainfall are October to February. The area has 12 day and 12 night hours. The area is prime agricultural land with good soils to support pastures.

The farm is 400 acres and supports 150 adult cattle, 50 calves, mainly Friesians, Ayrshire and a few Guernsey and 100 Dorper sheep. The main economic activity is dairy production.

Study animals

All the cattle that showed signs of eye disease (lacrimation, photophobia and corneal opacity) were recruited into the study and they totaled 25. They comprised of nineteen Friesians (4 adults, 8 heifers, 7 calves), three Ayrshires (2 adults, 1 heifer) and three Gurnsey (all heifers). The age classes were Adults > 24 months, Heifers >9 < 24 months and calves 1 to 8 months. Five Friesians (2 adults, 2 heifers and 1 calf) which had no clinical symptoms were also included as negative controls as they had no obvious symptoms of ocular infections. The animals had specific ear tag numbers and names. A total of thirty animals comprising of 8 adults, 14 heifers and 8 calves were selected.

Clinical Examination and sample collection

The ear tag number, name, breed and age of each of the study animals were recorded. The study animals restrained in a crush for close clinical examination and collection of conjunctiva swabs bacteriological evaluation.

Samples from the conjunctiva of both eyes of each study animal were taken with sterile cotton swabs. Each swab was rolled in the eye for about 30 seconds for each of the eyes. Care was exercised to avoid injury to the animal’s eye during sampling, and also contamination of the sample by the animal’s skin. It was done carefully to avoid touching the eyeball and any other part of the animal with the swab. The swabs were placed into a sterile labeled tubes corresponding to the ear tag numbers and transported with an hour to the laboratory for bacteriological analysis. A total of thirty samples were collected and submitted to the laboratory.

Bacteria culture and sensitivity tests

Each sample was streaked onto plates with blood agar and incubated aerobically at 37℃ for 24 hours. The colonial morphology was examined and described. Bacteria smears were made from individual colonies, stained with Gram stain for microscopic examination and identification of the bacterial organisms. Isolation and identification of *Morexiella bovis* were carried out according to previously described protocols [Holt, 1994].

Antibiotic sensitivity tests were done using Himedia KGL 2/4 octodisc impregnated with Ampicillin, Tetracycline, Streptomycin, Cotrimazole, Sulphamethazole, Kanamycin, Gentamycin, and Chloramphenicol and incubated at 37^0C for 24 hours.

RESULTS

The study animals comprised of 8 calves, 14 heifers and 8 adults while the breeds represented were 23 Friesians, 4 Aryshires and 3 Guernsey. The cattle with signs of ocular infection were in poor body condition, and were mostly yearling heifers. Most cases were unilateral, but bilateral eye infection was observed in one Ayrshire heifer. The signs noted were excessive lacrimation with matting of the facial hair, photophobia, with animals presenting with closing the affected eyes to avoid exposure to sunlight, reddening and swelling of the eyelids including the third eyelid (Figure 1).

Out of the 30 samples collected 10 (33%) were positive for *Moraxella bovis*, *Staphylococcus aureus* accounted for 18 samples (60%) while 2 samples (7%) were positive for *Escherichia coli*. Among the cases that were positive for *Moraxella bovis*, 6 were heifers, 3 calves and 1 adult, and on breed distribution the infections were observed in 8 Friesians, 1 Ayrshire and 1 Guernsey. The prevalence of *Moraxella bovis* infections was recorded at 6% of the herd with majority of the infections occurring in heifers. No eye infections were observed in the dorper sheep in this farm.

The colonial characteristic of *Moraxella bovis* showed scanty growth on blood agar of small round whitish colonies (Figure 2).

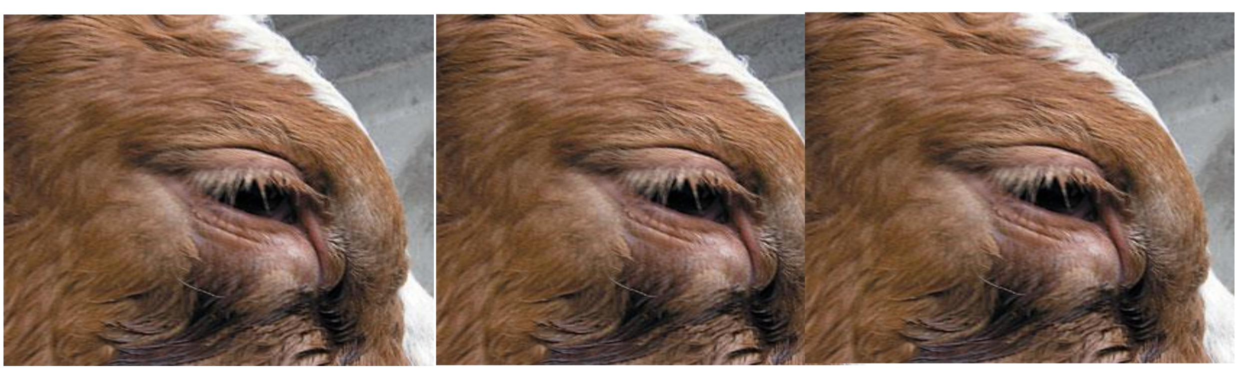

Figure 1: Ayrshire cow swollen eyelids, lacrimation and matting of facial hairs

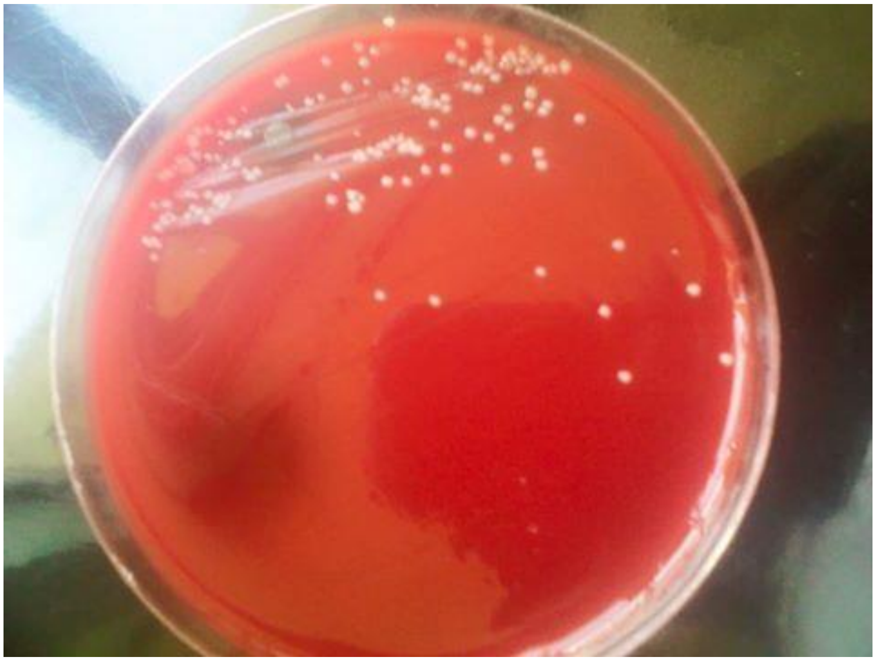

Figure 2: Colonial characteristics of *Moraxella bovis* on blood agar from eye infections of dairy cattle in Eldoret, Kenya

On microscopic evaluation, the organisms occurred in pairs and were gram negative bacteria.
The isolated organisms were sensitive to most of the antibiotics used, with largest zone of inhibition with ampicillin and Sulphamethazole having no effect (Figure 3).

Figure 3: Antimicrobial sensitivity test for the *Moraxella bovis* eye infections of dairy cattle in Eldoret, Kenya

High percentages of the cattle with signs of ocular infection were in poor body condition, and were mostly yearling heifers. Most cases were unilateral, but few animals with bilateral eye infections were present and were walking by making careful steps to avoid hitting objects this was witnessed mainly in heifer Ayrshire. Other signs noted were lacrimation leading to matting of the facial hair, many flies were seen around the eyes and the entire face feeding on the tears, photophobia presenting with animals were seen closing the affected eyes to avoid exposure to sunlight and corneal ulceration in some animals (Figure 1).

The common clinical findings in cases of ocular infections were; photophobia, blepharospasms and epiphora; later the ocular discharge may become mucopurulent, opaque areas in the center of the cornea appears in about two days, and by day six the entire cornea will have a gray-white to yellow color with deep central ulceration of the cornea. Some of the animals were blind either unilateral or bilaterally.

DISCUSSION

Most of the animals affected were heifers (46%) followed by calves (26%) a few adults were affected. Other findings included low weight gain in young animals and reduced milk yield in adults which has leads to high economic loss as well as treatment cost. These findings are similar to studies in Australia in beef cattle (Champness, 2008; Snowden *et al*., 2005).

The high prevalence of face flies (*Musca autumnalis*) suggested them as the main predisposing factors of this disease which is in agreement with the work of authors (Cheng, 1967). Other predisposing factors that are also found in this study included tall grasses which could cause irritation of the eyes and feeding of dry hay.

Ocular infections in Illula Dairy farm Eldoret lead to losses associated with decreased weight gain in young animals, reduced milk yield, costs of treatment and labor, with culling of most of the cattle. The treated animals recovered within three to five weeks, with only a few affected eyes having a persistent white scar on the cornea as reported by other authors (Coetzer and Tustin, 2004). In this study, though similar findings were reported, none of the cases developed the severe forms of the disease. This may be attributed to the prompt treatment of most cases due the presence of veterinarians and experienced herdsmen who reported most cases early. Most cases of eye infections have been reported in younger cattle**.** In this study, most cases of eye infections were in yearling heifers which are in agreement with the previous reports on this condition (Champness, 2008). This may be due to the low immunity in younger cattle since they are naïve.

The Staphylococcus aureus and *Escherichia coli* that are identified in this study were considered as commensal hence not cause of the eye infections observed.

In conclusion, *Moraxella bovis* were the only infectious agents isolated from eye infections in these cattle therefore it was the cause of this disease and occurrence of face flies was the main predisposing factor. The authors recommended prompt treatment of eyeinfections and control of flies particularly in the calf pens and milking parlour.

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1.5 Disorders of the claw and their association with laminitis in smallholder zero-grazed dairy cows

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Abstract
Lameness in dairy cattle adversely impact on productivity. A cross-sectional study was done in which 300 zero-grazed dairy cows from 29 smallholder dairy units were examined for claw lesions in the peri-urban areas of Nairobi, Kenya. The objective of the study was to determine the characteristics of claw disorders and their association with laminitis. Lameness for each cow was determined by assessing the locomotion score through a prescribed locomotion scoring system. Each cow was restrained in a crush and the claws thoroughly washed and examined for any claw external lesions or disorders including signs of laminitis. About 2 mm of the horn of the sole for each claw was trimmed to confirm laminitis by presence of sole haemorrhages. Data was analyzed using Genstart statistic software. Prevalence of laminitis was 70.3% out of which 49.3% was subclinical laminitis and 21.0% was chronic laminitis. Claw deformities found to be strongly associated with chronic laminitis were claw overgrowth ($\chi^2 = 96.69$, $r = 0.6$, $p < 0.0001$), horizontal grooves ($\chi^2 = 61.27$, $r = 0.5$, $p < 0.0001$), concave claws ($\chi^2 = 59.39$, $r = 0.4$, $p < 0.0001$), flat claws ($\chi^2 = 57.87$, $r = 0.5$, $p < 0.0001$), presence of sole haemorrhages ($\chi^2 = 50.16$, $r = 0.4$, $p < 0.0001$) double soles ($\chi^2 = 42.57$, $r = 0.4$, $p < 0.0001$) and white line separation ($\chi^2=37.78$, $r=0.4$, $p<0.0001$), while sole bruising was moderately associated with chronic laminitis ($\chi^2 =11.02$, $r = 0.2$, $p = 0.0009$). Sole haemorrhages were the only lesions strongly ($\chi^2=89.45$, $r=0.6$, $p<0.0001$) associated with subclinical laminitis. It was therefore concluded that chronic laminitis was strongly associated with deformity types of claw disorders and diffuse sole haemorrhages, while subclinical laminitis was strongly associated with only sole haemorrhages.
Key words: Lameness, sole haemorrhages, claw deformities, subclinical laminitis, chronic laminitis

INTRODUCTION

The physiological function of the bovine claw and the pathogenesis of non-infectious claw disorders depend on the state of pododermal microvasulature (Hisrschberg and Plendl, 2005). Biologically, laminitis is a systemic disease syndrome that primarily manifests in the claws, hence rightly being referred to as “claw horn disruption” (CHD), which is a term that more appropriately describes its main effects on the claws (Hoblet and Weiss, 2001). Impairment of the corium microvasculature resulting from altered systemic pH, as well as the action of circulating endotoxins and vasoactive substances triggers processes that lead to laminitis (Nocek, 1997; Cook *et al*., 2004). Laminitis initially develops as insidious subclinical form with delayed manifestation of the clinical symptoms. By the time it gets to the phase of clinical manifestation, the disruptive changes within the claw may already be irreversible (Greenough, 1987; Nocek, 1997; Belge and Bakir, 2005; Nguhiu-Mwangi, 2007; Nguhiu-Mwangi *et al*., 2008). Apart from causing lameness directly in cattle, laminitis through claw-horn disruption (Hoblet and Weiss, 2001) is also incriminated as a significant contributor to the occurrence of other non-infectious claw disorders such as white line separation, sole ulcers, heel erosion, sole bruising, double soles and sole haemorrhages (Smilie *et al*., 1991; Nocek, 1997; Belge and Bakir, 2005).

Laminitis may not drastically reduce productivity in dairy cows. However, due to its effects on the quality of the horn of the claws that predispose to the occurrence of other claw disorders and the irreversible damage within the claws, it may eventually have long-term effects on the performance of the dairy cow that may subsequently result in the culling of the animal (Nocek, 1997; Belge and Bakir, 2005).

Chronic laminitis in cattle causes gross misshaping of the claw that can easily be mistaken as mere hoof deformity (Rhebun and Pearson, 1982; Greenough, 1987). The claw is becomes more elongated, flattened, widened and the dorsal wall becomes concave (Greenough, 1987; Nocek, 1997), while horizontal ridges on the dorsal surface of the claw become deeper and more prominent, giving it a rippled appearance (Weaver, 1993; Nocek, 1997). Some of the lesions associated with laminitis can be evident externally, but others are more discernible only after trimming the horn over the sole and the white line (Nocek, 1997; Belge and Bakir, 2005).

It has been stated that laminitis could be the cause or result of some of the non-infectious claw disorders affecting dairy cows (Smilie *et al*., 1991; Nocek, 1997; Belge and Bakir, 2005), but its association with these claw disorders has not been presented in any literature. The purpose of this paper is therefore to show how subclinical and chronic phases of laminitis are associated with other non-infectious claw disorders in dairy cows.

MATERIALS AND METHODS

The study Area

The study was carried out in the urban and peri-urban areas of Nairobi County, Kenya. Nairobi is the capital city of Kenya with an area estimated at 696 square kilometers and a populated of over 3.1 million people. It lies between 01º18´S and 36º45´E. It is 1798 meters above the sea level and has an annual rainfall estimated at maximum of 765 mm and minimum of 36 mm with two distinct seasons of March to June and October to December. Nairobi and its surrounds have a high concentration of smallholder zero-grazed dairy units due to its ready market for milk and related milk products.

Selection of Study Smallholder dairy Units

A purposive selection of 32 smallholder zero-grazing dairy units was done. Each had 5-20 adult dairy cows. The median number of cows to the units was 10. Purposive selection method was used because of the difficulties of farmers allowing their animals to be used for the study, hence it was based on the willingness of farmers to participate and to allow their cows to be used. The farms were selected with the assistance of local veterinarians and veterinary paraprofessional workers with whom the farmers were acquainted.

Selection of the cows

A total of 300 dairy cows were selected for the study from the 32 smallholder zero-grazing dairy units. A cow qualified to be recruited into the study population if she had calved at least once. Among the cows that were selected, 40% were in the 1^{st} or 2^{nd} parities and 60% had 3 or more parities. Lame and non-lame cows were included in study. They included the four main dairy breeds, which were Friesian, Ayrshire, Guernsey and Jersey or their cross breeds.

The cows were selected using simple systematic sampling method in which the cows that met the selection criteria in each smallholder zero-grazing unit were serially tagged with numbers 1, 2, 3,-- n, where n was the serial number of the last cow with selection criteria in the unit. The assigning of the serial numbers to the cows was randomly done by a farm worker who was not aware of the research objectives in order to avoid being biased. The investigator then did the systematic sampling of the serially numbered cows in each unit by selecting every alternate cow within the serial numbers. For example cow numbers 1, 3, 5, 7-- n or 2, 4, 6, 8-- n until the last cow within the smallholder zero-grazing unit. Therefore the cows within a unit that met selection criteria were either all picked from only even numbers or only odd numbers. For any smallholder zero-grazing unit that had less or up to a total of 5 eligible cows, all of them were included in the study, but systematic sampling was done only for units with more than 5 eligible cows.

Examination of the Selected Cows

Each of the selected cows was assessed for lameness using a locomotion scoring system adapted from Sprecher *et al*. (1997). This was followed by each cow being restrained in a crush for examination of claw disorders. In most of the smallholder zero-grazing units, the restraint facilities were poor and therefore only the hind limbs were examined because of the difficulties of accessing the forelimbs while the cows were within these facilities. Moreover, it is clearly known that a higher percentage of claw disorders in cattle affect mainly the hind limbs (Tranter *et al*., 1993), hence examining the hind limb would be a reliable indicator of the claw disorder status.

With the cow well restrained in a crush, each hind limb claw was evaluated on the dorsal surface for signs of laminitis and other disorders. Each limb was raised off the ground by fastening it with a rope tied to an overhead cross-bar, thoroughly washed and the sole examined for any gross lesions. A 1-2 mm thickness of the horn of the sole was trimmed-off using a quittor knife in order to expose any underlying lesions. Trimming was non-invasive because it did not reach the level of the corium, hence no pain was caused to the cows. Foot anaesthesia using 2% lignocaine hydrochloride was applied when examining any cow with painful claw lesions.

Each claw lesion was pre-coded with a specific code number and recorded in designated data entry forms using a simple numerical system. Numerical "1" was used for presence of subclinical, chronic laminitis or a claw disorder and numerical "0" for absence of claw disorders (i.e. when the claw was normal). The "1" or "0" entries made it easier and convenient to important the data into computer analysis software. Diagnosis of laminitis was mainly based on presence of haemorrhages occurring on the weight-bearing surfaces of the claws as red or yellow discolourations. The haemorrhages would either be on one or more zones of the weight-bearing surface and would either occur alone or concurrently with other non-infectious claw lesions such as sole bruising, sole ulcer, heel erosion, white line separation and double soles (Nocek, 1997; Belge and Bakir, 2005). Normal-looking claws but with sole haemorrhages were diagnosed as having subclinical laminitis, but those with sole haemorrhages concurrently with other claw disorders/deformities were diagnosed as having chronic laminitis. Those with no sole haemorrhages were diagnosed as having only the manifesting disorder.

Location of each lesion on the weight-bearing surface of the claws was classified according to the 6 conventional zones as described by Greenough and Vermunt (1991) as shown in Fig. 1.

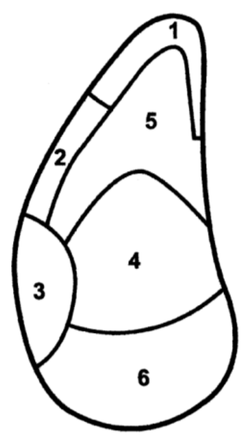

Fig. 1: Zones of the weight-bearing surface of the claws of cattle (Greenough and Vermunt, 1991). **Key to Figure 1:** Zone 1-*white zone at the toe*, Zone 2 - *abaxial white zone*, Zone 3 - *abaxial wall-bulb junction*, Zone 4 – *sole-bulb junction*, Zone 5 – *apex of the sole*, Zone 6 – *heel bulb*.

The distribution of haemorrhages on the weight-bearing surfaces of the claws was also categorized according to 5 conventional haemorrhage scores also described by Greenough and Vermunt (1991), which is presented in Table 1.

Table 1: the 5-score scale of sole haemorrhages that occure on the weight-bearing surface of the claws of cattle (Greenough and Vermunt, 1991)

Score	Description
0	No haemorrhages
1	Slight discolouration
2	Moderate discolouration
3	Severe haemorrhages
4	Exposed corium

DATA MANAGEMENT AND ANALYSIS

The data were stored in Microsoft Office Excel 2003 (Microsoft Corporation, 2003) spread sheets. They were cleaned, verified and validated to be correct as per the entries from the record sheets. The data were imported into SAS© 2002-2003 (SAS Institute Inc. Cary, NC, USA). Descriptive statistics were computed for each claw disorder per cow and then for the entire study population. The prevalence rate of each claw disorder was calculated independent of other claw disorders. It was calculated as the number of cows (CL) affected by the specific claw disorder divided by the total number of cows (300) examined multiplied by 100 to give the percentage (%).

$$Prevalence\ (\%) = \frac{CL \times 100}{300}$$

After descriptive statistics, the test of association between laminitis and the non-infectious claw disorders and the manifesting symptoms was done in three stages. The first stage was Chi-square (χ^2) statistics to test for unconditional associations as well as strength of those associations between laminitis and the other claw disorders at the 5% significant level ($p < 0.05$) and also the correlation coefficient (r) for direction of the associations. The second stage was multiple logistic regression models that factored all the claw disorders against subclinical and chronic phases of laminitis. These also revealed both the strength and direction of the associations using β-estimate (β-e) and odds ratio (O.R.). The third stage was stepwise logistic regression models, which revealed the claw disorders that were invariably associated with the two phases of laminitis being considered. The effects of confounding among the claw disorders in contributing to the associations were dealt with in the analysis through the stepwise selection of the factored claw disorders.

RESULTS

The results of this study revealed that the dairy cows in the smallholder zero-grazing units in the urban and peri-urban areas of Nairobi had a 70.3% prevalence of laminitis of which 49.3% was subclinical and 21% was chronic. There was also relatively high percentages of occurrence of claw disorders other than laminitis, such as haemorrhages (52%), sole bruising (45%), overgrown claws (30.3%), heel bruising (27%), white line separation (18%), horizontal ridges (17.8%), double (underrun) soles (17%) and flattened claw (12%). Claw infections had low percentage (4.7%). The percentages of occurrence of these claw disorders are summarized in Table 2.

Table 2: Prevalence of laminitis and the non-infectious claw disorders that were found during prospective cross-sectional study in dairy cows in 32 smallholder zero-grazing units in urban and peri-urban areas of Nairobi, Kenya.

Claw disorders	Number of cows (n = 300)	Prevalence (%)
Subclinical laminitis	148	49.3
Chronic laminitis	63	21.0
Sole haemorrhages	156	52.0
Sole bruising	135	45.0
Overgrown claws	91	30.3
Heel erosion/bruising	82	27.3
White line separation	54	18.0
Horizontal ridges on dorsal wall surface	53	17.8
Double (underrun) soles	51	17.0
Flattened claws	36	12.0
Concaved claws	15	5.0
Corkscrew claws	14	4.7
Sole ulcer	8	2.7

NB: *Some of the cows had more than one claw disorder per claw, hence the reason for total number adding to more than 300 and prevalence of all claw disorders adding to more than 100%.*

Correlation coefficient (r) and chi-square (χ^2) statistics indicated that subclinical laminitis has significant positive and strong association with sole haemorrhages ($r = 0.5$, $\chi^2 = 89.45$m $p < 0.0001$). The haemorrhages associated with subclinical laminitis were

invariably observed in zone 4 of the weight-bearing surface of the claw and this was significant ($r = 0.3$, $\chi^2 = 22.83$, p
< 0.001) and occasionally but significantly in zone 6 ($r = 0.1$, $\chi^2 = 5.87$, $p < 0.0154$) (Table 3).

Table 3: Correlation between subclinical laminitis and non-infectious claw disorders in dairy cows examined during the prospective cross-sectional study in 32 smallholder zero-grazing units in urban and peri-urban areas of Nairobi, Kenya.

Claw disorders	**Number of cows With each claw disorder (n =300)**	χ^2	**r-value**	**p-value**	**Direction of association**
Sole haemorrhages	156	89.44	0.6	< 0.0001	Positive
Sole haemorrhages in zone 4	104	22.84	0.3	< 0.0001	Positive
Sole haemorrhages in zone 6	42	5.87	0.1	0.0154	Positive
Overgrown claws	91	15.94	-0.2	< 0.0001	Negative
Concaved claws	15	15.37	-0.2	< 0.0001	Negative
Flattened claws	36	14.62	-0.2	< 0.0001	Negative
Corkscrew claws	14	14.30	-0.2	0.0002	Negative
Horizontal grooves	53	6.09	-0.1	0.0136	Negative

NB: *Some of the cows had more than one claw disorder per claw, hence the reason for total number adding to more than 300.*

The degree of haemorrhages associated with subclinical laminitis was slight to moderate (score 1 and 2) as described in Table 1. However, through multiple logistic regression and stepwise logistic regression models, it was found that the only claw disorders having significant strong positive association with subclinical laminitis were the occurrence of sole haemorrhages (β-e = 3.672, O.R. = 39.33, $p = 0.0072$), particularly in zone 4 (β-e = 1.399, O.R. = 4.05, $p < 0.0001$) as shown in Tables 4
The claw disorders that had weak positive significant association with subclinical laminitis were sole bruising (β-e = 0.821, O.R. = 2.27, $p = 0.0093$) and heel bruising (β-e = 0.820, O.R. = 2.27, $p < 0.0139$) (Table 4). The rest of the claw disorders observed were negatively associated with subclinical laminitis as shown by correlation coefficient and β-estimate values (Tables 3 and 4).

Table 4: Results of multiple logistic regression models on associations between subclinical laminitis and non-infectious claw disorders in dairy cows examined in a prospective cross-sectional study in 32 smallholder units in urban and peri-urban areas of Nairobi, Kenya.

Claw disorders	β-estimate (β-e)	S.E (β)	Odds ratio (O.R.)	95% C.I.	χ^2	p-value
Sole haemorrhages	3.672	1.367	39.33	2.70-573.14	7.22	0.0072
Sole ulcer	-2.213	1.105	0.11	0.01-0.95	4.02	0.0451
Horizontal grooves	-1.559	0.469	0.21	0.08-0.53	11.07	0.0009
Sole bruising	0.821	0.315	2.27	1.22-4.22	6.77	0.0093
Heel bruising	0.820	0.334	2.27	1.18-4.37	6.05	0.0139

NB: S.E (β) = standard error of β, CI = confidence interval

Overgrown claws, horizontal grooves on the dorsal surfaces of the claws, concave shape of the dorsal wall of the claw, flattened claws, corkscrew claws, double (underrun) soles, white line separation, sole bruising and presence of haemorrhages on the weight-bearing surfaces of the claws were all found to have strong positive significant association with chronic laminitis (Table 5). Unlike in subclinical laminitis, the sole haemorrhages associated with chronic laminitis were found to be severe in scores 2 and 3, which was significant (χ^2 = 50.16, p < 0.0001). These haemorrhages were widely distributed in most zones on the weight-bearing surface of the claws and have varied strength of associations with chronic laminitis as follows: zone 2 (χ^2 = 18.24, p < 0.0001), zone 3 (χ^2 = 23.45, p < 0.0001), zone 4 (χ^2 = 11.05, p = 0.0009), zone 5 (χ^2 = 5.23, p = 0.0222) and zone 6 (χ^2 = 4.48, p = 0.0304) as shown in Table 6. Sole ulcer was weakly but significantly associated (r = 0.118, χ^2 = 4.16, p = 0.0412) with chronic laminitis. Although multiple regression models showed that all these claw disorders were significantly associated with chronic laminitis (Table 7), stepwise logistic regression models indicated the only claw disorders that were invariably significant with chronic laminitis were overgrown claws (β-e = 3.006, O.R. = 10.93, p < 0.0001) and deep horizontal grooves on the dorsal wall of the claws (β-e = 2.196, O.R. = 12.30, p < 0.0001).

Table 5: Correlation between chronic laminitis and non-infectious claw disorders in dairy cows in a prospective cross-sectional study in 32 smallholder zero-grazing units in urban and peri-urban areas of Nairobi, Kenya.

Claw disorders	**Number of cows with each type of claw disorder**	χ^2	**r-value**	**p-value**	**Direction of association**
Overgrown claws	91	96.69	0.6	< 0.0001	Positive
Horizontal grooves	53	61.27	0.5	< 0.0001	Positive
Concaved claws	15	59.39	0.4	< 0.0001	Positive
Flattened claws	36	57.87	0.4	< 0.0001	Positive
Corkscrew claws	14	45.71	0.4	< 0.0001	Positive
Double (underrun) soles	51	42.57	0.4	< 0.0001	Positive
White line separation	54	37.78	0.4	< 0.0001	Positive
Sole bruising	135	11.02	0.2	0.0009	Positive
Sole ulcers	8	4.16	0.1	0.0412	Positive
Sole haemorrhages	156	50.16	0.4	< 0.0001	Positive
Haemorrhages zone 2	38	18.23	0.2	< 0.0001	Positive
Haemorrhages zone 3	43	23.45	0.3	< 0.0001	Positive
Haemorrhages zone 4	104	11.05	0.2	0.0009	Positive
Haemorrhages zone 5	26	5.23	0.1	0.0222	positive
Haemorrhages zone 6	42	4.48	0.1	0.0343	positive

Table 6: Results of multiple logistic regression models on associations between chronic laminitis and non-infectious claw disorders in dairy cows examined in a prospective cross-sectional study in 32 smallholder zero-grazing urban and peri-urban areas of Nairobi, Kenya

Claw disorders	β-estimate (β-e)	S.E. (β)	Odds ratio (O.R.)	95% CI	χ^2	p-value
Sole haemorrhages	4.397	4.056	0.3	0.03-2.45	39.92	< 0.0001
Haemorrhages zone 2	6.040	4.257	13.7	1.11-167.30	19.60	< 0.0001
Haemorrhages zone 3	6.132	4.178	24.8	1.89-327.21	23.63	< 0.0001
Haemorrhages zone 4	61.630	4.194	4.0	0.42-38.45	11.74	< 0.0001
Haemorrhages zone 5	4.990	4.087	7.06	0.60-83.35	5.99	0.0144
Haemorrhages zone 6	7.227	4.253	17.70	1.49-210.79	4.54	0.0332
Overgrown claws	2.402	0.817	11.04	2.23-54.74	93.55	< 0.0001
Flattened claws	3.543	1.037	34.56	4.53-263.74	93.55	< 0.0001
Horizontal grooves	2.553	0.705	12.84	3.23-51.07	60.62	< 0.0001
Sole ulcer	1.573	1.523	4.82	0.24-95.45	4.19	0.0406
Sole bruising	1.840	0.821	6.30	1.26-31.47	10.24	0.0014
White line separation	2.352	0.828	10.50	2.07-53.26	35.08	< 0.0001
Double (underrun) soles	3.035	0.856	20.80	3.88-111.33	39.70	< 0.0001

DISCUSSION

The high prevalence of laminitis and non-infectious claw disorders has been attributed to presence of cow-level and farm-level risk factors prevailing within the smallholder dairy systems in the zero-grazing units (Nguhiu-Mwangi *et al.*, 2008). The low plane concentrate feeding in these smallholder dairy systems only predisposes to the occurrences of subclinical and chronic laminitis rather than acute laminitis, which is normally associated with high level of grain feeding.

The results of this study indicate that all cows with subclinical and chronic laminitis invariably had sole haemorrhages as previously documented (Nocek, 1997; Belge and Bakir, 2005). However, the severity of haemorrhages and the zones on the weight-bearing surface of the claw in which the haemorrhages were found varies between subclinical and chronic laminitis. Strong positive association between sole haemorrhages and laminitis could be attributed to changes in pododermal microvasculature that occurs in laminitis, which results in transvascular seepage of serum that manifests as haemorrhagic discolourations in the horn of the sole (Nocek, 1997; Hirschberg and Plendl, 2005). It has further been reported that a number of claw-horn lesions initially develop as haemorrhages of the sole or white line (Vermunt and Greenough, 1991).

The invariable association of haemorrhages in zones 4 and 6 with subclinical laminitis could be explained by the fact that the horn in these zones is thinner than the rest of the zones, hence the haemorrhages that occur in the corium would show on the surfaces of these zones and then later in chronic laminitis appear on the surfaces of the zones with thick horn (Nguhiu-Mwangi *et al*., 2007). Furthermore, the initial pathogenesis of subclinical laminitis involves the process of extravascular escape of blood components into the tubules of the horn of the sole and the heel bulb (Greenough and Vermunt, 1991), with haemorrhages gradually becoming visible on the surface of the sole over a period of time, hence sole haemorrhages are a good indicator of subclinical laminitis (Shearer and van Amstel, 2000; Nguhiu-Mwangi *et al*., 2007). This explains the fact that by the time laminitis advances to chronic phase, the haemorrhages are widely spread to most zones of the weight-bearing surface of the claw. Moreover, the deformities that occur in chronic laminitis result in shifting of weight-bearing to the sole-heel junction area which is weaker. This exacerbates microvascular damage in the corium, leading to more severe and widespread sole haemorrhages in chronic laminitis than in subclinical laminitis (Greenough and Vermunt, 1991; Nocek, 1997).

Association of sole bruising and heel erosion with subclinical laminitis may result as a cascade of processes. In these processes, subclinical laminitis causes production of weak horn that is easily bruised/eroded at the sole and the heel. Bruised and eroded horn of the sole and heel become excessively thin, allow easy transmission of pressure to the corium from the treading ground against the weight of the cow particularly in zones 4 and 6 (Shearer and van Amstel, 2000). This causes microvascular damage within the corium, which predisposes to occurrence of subclinical laminitis, subsequently leading to production of weak horn. This cascade cycle continues.

Claw deformity disorders shown to have positive strong association with chronic laminitis can probably be attributed to the disruption of the growth of keratinized horn during laminitis, which subsequently alters the shape of claws, thus making them longer, flattened and broadened (Nocek, 1997). The dorsal angel becomes markedly reduced, while the dorsal wall becomes shaped to concave (Weaver, 1993). It is this misshaping of the claws that makes the chronic laminitis be mistaken as claw deformity (Rhebun and Pearson, 1982; Greenough, 1987) with the affected cow developing abnormal gait and lameness. Presence of any of these claw shapes concurrently with characteristic rippled appearance of the dorsal surface due to prominent horizontal grooves (Weaver, 1993; Nocek, 1997), could positively indicate presence of chronic laminitis. Moreover, laminitis is incriminated as a predisposing cause for development of claw deformities (Greenough, 1987; Weaver, 1993). Conversely, the resulting misshaping of the claws enhances more laminitis by altering the altering the treading angle with more weight-bearing on the softer parts of the sole towards the heel, which in turn leads to transmission of traumatic pressure into the underlying corium.

The association of some claw conditions such as double (underrun) soles, white line separation, sole bruising, white line separation, sole ulcer and heel erosion with chronic laminitis is probably related to the fact that chronic laminitis is reported to be a predisposing cause to these conditions (Nocek, 1997; Smilie *et al*., 1999; Belge and Bakir, 2005). Severe microvascular haemorrhages in the corium leads to accumulation of blood/serum between the corium and the horn of the sole. This eventually causes separation of the horn from the underlying corium. The new horn produced by the corium is separate from the old horn and this results in double soles with outer old horn and inner thin new horn (Nocek, 1997). The formation of double soles is a process that occurs in chronic laminitis and not in subclinical laminitis, which explains its strong association with chronic laminitis.

Similarly, the white line zone is naturally the weakest point of impact on the weight-bearing surface of the claws and easily succumbs to avulsion under pressure of the weight of the animal against the treading ground (Baggott and Russell, 1981). During laminitis, the white line zone becomes even more vulnerable to avulsions owing to softening and impairment of the horn, which is more prevalent in chronic laminitis (Nocek, 1997; Smilie *et al*., 1999; Belge and Bakir, 2005).

The cows found with sole ulcers in this study had very advanced laminitis. It has been reported that in chronic laminitis, the pedal bone changes its configuration and drops distally, compressing the corium towards the horn of the sole. The horn then gives way at the axial part of zone 4 and 5, hence resulting in sole ulcer that exposes the corium to protrude externally, which explains how sole ulcer is associated with chronic laminitis (Baggott and Russell, 1981; Hull, 1993; Nocek, 1997).

It is therefore concluded from the findings of this study that non-infectious claw disorders in cattle are strongly associated with laminitis. The subclinical phase of laminitis being strongly and invariably associated with sole haemorrhages particularly in zones 4 and 6 of the weight-bearing surface of the claw, while chronic laminitis being strongly associated with deformities that cause disorders of the claws. However, laminitis can be the “cause” or the “effect” of non-infectious claw disorders. The main risk factors of laminitis and the non-infectious claw disorders in the dairy cows in the smallhoder zero-grazing units are comprehensively described in a previous publication (Nguhiu-Mwangi *et al*., 2008).

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1.6 Participatory technology transfer and impact in poultry production and marketing: The case of farmers in Makueni County

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Abstract

Indigenous chickens (IC) constitute 80% of the poultry population in Kenya and kept by over 80% of rural households. They contribute to household food security, income and social-cultural roles. Demand for IC and their products has increased in urban areas without corresponding increase in productivity at farm level. A research project was undertaken in Makueni County where constraints to IC production and marketing were identified, followed by implementation of appropriate interventions. The intervention strategy entailed participatory technology development and transfer with farmers. A survey was then conducted in the study area post-project, aimed to evaluate the uptake and impact of the interventions. Primary data was collected from a sample of 40 farmers using a structured questionnaire and direct observations. Data was analysed using descriptive statistics. Results of the survey showed positive change between the ante- and post-project periods. The flock sizes per household increased, with farmers keeping more of improved indigenous chicken (IIC) ecotypes than the local IC. The productive performance of IIC was higher compared to that of IC. The mean age at onset of lay was 28 months for IC hens and 23 months for IIC while the corresponding number of eggs laid per hen per year was 43 compared to 74. The marketing price of eggs was on average Ksh. 9 and 13 for IC and IIC, respectively. Owing to a faster growth rate, the IIC birds were marketed earlier than IC (21 versus 27 weeks of age) and fetched a higher price of Ksh. 531 compared to Ksh. 420 for IC. Hatchability and survivability rates for all birds increased to approximately 90 and 86%, respectively. Proper housing of birds and usage of brooders for chick rearing increased. Almost all farmers (97.5%) practiced

disease control measures while a similar percentage formulated their own feeds and supplemented their flocks twice per day post-project. The significant impact from the study highlighted the importance and effectiveness of participatory technology development and transfer methods when working with rural communities. Such methods provide for faster and more sustainable gains in technology adoption, improved farm productivity and incomes, hence improved livelihoods.

Key words: Indigenous chicken, farmers, interventions, participation, impact

INTRODUCTION

The poultry industry is estimated to contribute 33% of the total global meat consumption and this proportion is anticipated to increase at 2 -3% per year (Mengesha, 2013; FAO, 2012). Poultry production remains a vital economic activity among smallholder farmers in developing countries (Vincent et al., 2010). According to Kryger *et al.,* (2010), an estimated 80% of rural households in developing countries recognize poultry production as a major economic activity. Indigenous chicken (*Gallus domesticus*) constitute over 70% of the total chicken population (FAO, 2011). Moreover, 47% and 55% of eggs and poultry meat respectively, in Kenya are derived from indigenous chicken (King'ori *et al.,* 2012). Therefore, indigenous chicken is a promising subsector in Kenya and especially to small-scale farmers whose production constitutes 80% of the national poultry production (RoK, 2012).

Indigenous chicken production creates an avenue towards addressing food insecurity and this translates to improvement of livelihoods among many rural households (Magothe *et al.,* 2012). This is also the case for Makueni County located in an arid and semi-arid region where IC is reported to positively contribute to the livelihoods of many households (Kabuage, 2010). Indigenous chicken distribution remains wide in both rural and peri-urban areas and plays a crucial role in food production and generation of income (Okello *et al*., 2010). The IC products (meat and eggs) serve as a cheap source of animal protein, while reliability to source petty cash from IC is highly recognized (Adomako *et al*., 2009).

Rearing of IC is preferred because the birds are hardy and well adapted to harsh environments, survive well on low inputs and are efficient in feed conversion (King'ori *et al.,* 2010). Moreover, their products (meat and eggs) are preferred for leanness and good taste. Previous studies reported that consumers' preference for IC products has triggered increased demand (Bett *et al.,* 2012; Ndenga *et al.,* 2017). The demand has also been linked to population growth, urbanization, health concerns and increased per capita income which is projected to increase consumption by the year 2020 (USAID, 2010). According to WSPA (2012), there exists an unmet demand for indigenous chicken products (meat and eggs). Consumers are therefore willing to pay a premium price for IC products (Bett *et al.,* 2012; Ndenga *et al.,* 2017).

Despite the importance of IC, the growth of this subsector is constrained by various factors which include; poor nutrition, poor housing, low genetic potential, feed shortages and diseases, leading to low productivity (RoK, 2012; King'ori *et al.,* 2010). Outbreak of diseases such as; New Castle Disease, fowl typhoid and Gumboro in Kenya accounts for approximately 50% of the total IC losses (Olwande *et al.,* 2010). To address the stated constraints, various technological interventions at farm level would be required. These include: proper housing, feed supplementation, disease and pest control, and improved IC genotypes. Implementation of such technologies would be expected to improve IC productivity among smallholder farmers in rural households (RoK, 2012; Njuguna *et al.,* 2017). Enhanced productivity would consequently boost financial returns and help to address the grinding poverty experienced by most rural households.

As a pertinent strategy to increase IC productivity, various rural development stakeholders such as the Kenya Agricultural Productivity and Agribusiness Project (KAPAP) have made efforts to intervene through supporting extension and research projects in selected counties. The current study presents the results of intervention impact generated by a KAPAP supported research project that was implemented in Makueni County to promote indigenous chicken production and marketing. The project entitled 'Promotion of indigenous chicken value chain in Makueni County, Kenya' was undertaken in two phases. The first phase entailed participatory identification of constraints to IC production and marketing through a mapping survey conducted along the indigenous chicken value chain (ICVC). Phase two involved formulation and implementation of identified appropriate interventions at farm level. The intervention strategy for the project entailed participatory technology development and transfer with farmers in Makueni for one year.

A post-project survey was thereafter conducted in the study area, aimed to evaluate the uptake and impact of the implemented intervention technologies in the project areas in Makueni County. This paper was therefore intended to show the results of the impact evaluation and to depict the situation in the ante- and post-project periods in the County.

MATERIALS AND METHODS

Study area

Makueni County is located in the Southern part of Eastern Kenya. It lies between latitude 1°35′ South and Longitude 37°10′ East and 38°30′ West East (RoK, 2010). The county comprises of an area of 8008.8 Km^2. Temperatures range between 12-28 ^oC, with bimodal rainfall ranging from 150-650 mm per annum, typical of the arid and semi-arid lands (ASALs) in Kenya (RoK, 2010). Low rainfall and high temperatures in this county hinder crop production thus livestock production remains a priority. The county is located in areas considered to have favourable agro-ecological conditions for production of IC and is listed amongst leading areas in IC production in Kenya (KARI, 2011; MoLD, 2011). The County has high poverty levels but indigenous chicken are found in almost all households. The research project covered two Sub-counties but the main site for the current study was located in Wote Sub-county of Makueni.

Data collection and sampling procedure

The intervention through dissemination and implementation of improved poultry production and marketing technologies by the KAPAP Project was done in the 2014-2015 period. This followed a comprehensive mapping and identification of constraints and opportunities in poultry production and marketing, using participatory methodology. The intervention strategy entailed participatory technology development and transfer with farmers. A broad range of key management technologies was disseminated and implemented in over 200 target households. The technologies included: feed formulation, feeding and supplementation, proper housing, bio-security and disease control, use of artificial brooders and rearing of improved indigenous chicken (IIC) ecotypes. One month old IIC chicks were distributed by the project to the target households.

The impact survey that forms the subject of this paper was conducted after the end of the project in 2015. A purposive sampling procedure was used to select a sample of 40 households. A structured questionnaire was administered to collect primary data. This was further strengthened by direct observation of farm facilities and records. Secondary data was obtained from the livestock office located in Wote, Makueni County. Data analysis was done through descriptive statistics.

RESULTS AND DISCUSSION

The following section presents the results of impact of the disseminated technologies on IC performance among the target farmer groups in Makueni County.

Distribution of target farmers

Figure 1 shows how farmers were distributed in the various study sites in Makueni County which included: Kamunywolo, Mbimbini and Kikumini locations. The evaluation involved 12 farmers from Kamunywolo, 22 from Mbimbini and 6 from Kikumini location. The 22 farmers from Mbimbini constituted the Uviluni common interest group (CIG) whereas the other 18 farmers belonged to the Mwang'a/Mang'auni CIG.

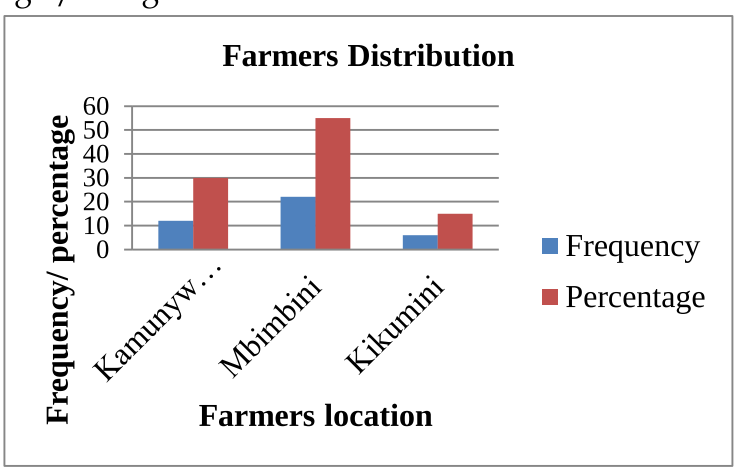


Figure 1: Distribution of target farmers in three locations

Household flock size and composition

The results in Table 1 illustrate the diffusion of the improved indigenous chicken technologies in the selected locations. Before the project, the target farmers had a mean flock size of 23 birds, of which 19 were local indigenous chickens. The flock size post-project had increased to an average of 34 birds comprising 26 improved indigenous chicken (IIC) and a reduced number of local IC (LIC) at only 8 birds. The percentage of IIC had risen from the initial 17.39% of the flock to a high of 73.53%, indicating an improvement of 56.14%. The evaluation results therefore showed a major increase in overall household flock sizes and more remarkably, a different flock composition comprising more IIC and fewer local IC. The new composition was expected to significantly enhance household flock productivity due to the higher performance of IIC compared to that of local IC. It was also an indicator that majority of the farmers had focused their attention towards rearing the improved indigenous chicken by reducing the number of the local indigenous chicken in their flocks.

To boost the small household flock sizes and productivity, the project had earlier intervened by giving the target farmers an average of 15 one month old IIC chicks. The evaluation results reflected the cumulative impact of interventions arising from the distributed chicks and their far better performance in terms of growth and reproduction, and also the improved productivity associated with implementation of the other disseminated poultry management technologies.

Table 1: Flock size and composition before, during and after project

Local and Improved Indigenous Chicken	Mean	Std. Err.
Flock composition before, during and after project		
Local indigenous chicken before project	19.25	2.72
Improved indigenous chicken before project	3.65	0.91
Total number of improved chicks received	14.5	0.94
Post-project flock size and composition	34.1	3.48
Improved indigenous chicken	25.83	3.46
Local indigenous chicken	8.28	1.60

Std. Err. – Standard Error:

Source; Own computation, 2016

Results demonstrating the performance of both local indigenous chicken and improved indigenous chicken ecotypes are presented in Table 2. The performance parameters used included: age at onset of lay, average number of eggs per clutch, number of clutches/hen/year, total number of eggs/hen/year, size of an egg, age at selling of birds, and the relevant prices .

Table 2: Comparison on performance of improved indigenous chicken (IIC) with local indigenous chicken (LIC) on-farm

Parameter	Improved Indigenous Chicken(IIC)		Local Indigenous Chicken(LIC)	
	Mean	Std. Err.	Mean	Std. Err.
Age at first egg lay (months)	22.78	0.52	27.78	1.15
Number of clutches/hen/year	3.48	0.18	3.08	0.15
Av. number of eggs/clutch	21.95	1.15	13.33	0.67
Total number of eggs/hen/year	74.18	2.99	43.35	2.57
Age at selling of birds (months)	21.20	1.24	27.03	1.79
Avg, selling price of birds (Ksh)	530.60	31.39	421.40	26.38
Price of an egg (Ksh)	12.80	0.84	9.10	0.73
Size of an egg (Visual assessment, scale[a] 1-3)	2.73	0.11	1.60	0.12

Source; Own computation, 2016. [a]Scale 1-3, where: 1-2 = Small (45-50 grams); 2.1-3 = Medium (51-55 grams); 3.1-4 = Large (56-60 grams)

The results in Table 2 demonstrated the superior performance of improved indigenous chicken compared to that of local indigenous chicken, thus indicative of the benefits accruing from rearing more of the IIC. The average age of hens at onset of lay for the IIC was 23 weeks whereas that of LIC was 28 weeks. The number of clutches/hen/year was similar for both breeds at an average of 3 clutches though the deviation showed that IIC had more than 3 clutches. The IIC hens rarely got broody, thus the prospects of using them to incubate eggs were rare as expressed by majority of the farmers. This led to prolonged laying cycles for IIC compared to the LIC.

The average number of eggs/clutch for the IIC was 22 eggs while that of LIC was 13eggs. This clearly pointed at the positive impact of IIC through laying more eggs compared to the local indigenous chicken. The total number of eggs/hen/year for IIC was 74 eggs whereas that of the local indigenous chicken was only 43 eggs.

The results further indicated that majority of the farmers sold their indigenous chicken to available markets in Makueni County. Most of the farmers sold their IIC at an average age of 21 weeks at a selling price of Ksh. 531. The local indigenous chicken were sold at an age of 27 weeks of age for an average of Ksh. 420. This clearly indicated that IIC reached the market age and size faster compared to that of the local indigenous chicken. The difference in prices revealed higher preference for the IIC compared to the LIC, demonstrating superior quality for these birds.

The average selling price of an IIC egg was Ksh. 13 whereas that of the LIC was Ksh. 9. This indicated the IIC eggs were considered superior by consumers, hence the higher price. Majority of the farmers also confirmed that most of the buyers preferred buying IIC eggs for hatching purposes. This further propelled the demand for these eggs leading to farmers increasing the prices. It was also notable that the average size of IIC eggs was larger at about 51-55g per egg while the LIC eggs were of small size, weighing about 45-50g. The larger eggs from IIC were therefore preferred for both consumption and hatching, with the latter aimed at yielding higher performing chicken ecotypes.

Table 3 shows the hatchability and survivability of the indigenous chicken before and after the project. The farmers practiced natural hatching by setting the available eggs to broody hens, with the objective of hatching by 21 days. This simple and low cost method of getting chicks was considered as convenient hence the best by farmers, for expanding their flock sizes.

Table 3: Hatchability and survivability of the indigenous chicken

Parameter	Before the project		After the project	
	Mean	Std. Err.	Mean	Std. Err.
Eggs set for hatching	10.78	0.58	13.25	0.72
Av. No. of chicks hatched/hen	7.95	0.53	11.98	0.62
Av. No. of chicks weaned/hen	4.40	0.52	10.35	0.69

Source; Own computation, 2016

Before the project, majority of the farmers set an average of 11 eggs for hatching by a broody IC hen. After the project, results showed that the average number of eggs set had increased to 13 eggs, mainly attributed to increased availability of eggs from IIC. The average number of chicks hatched per hen before the project was 8 whereas this number rose to 12 chicks by the end of the project (Table 3). The computed hatchability rate before the project was therefore 73.78% but this increased to 90.38% post-project.

The hatchability rate was computed as: $\frac{\text{Average number of chicks hatched}}{\text{Number of eggs set for hatching}} \times 100$

These results demonstrated a positive impact from the training of project farmers on selection of eggs for hatching and improvement of the hatching environment. Farmers had been trained to always consider the critical factors that influence hatchability, with emphasis on proper egg handling, optimal storage conditions, age and size of eggs, before setting for hatching purposes.

The survivability rate was computed by considering the number of chicks that reached weaning stage (8weeks) out of the total number that hatched. The results well illustrated the situation before and after the project. Before the project, the survivability rate was 55.35%, but this increased to 86.43% post-project. The increment was attributed to the training of farmers on vaccination, bio-security and other disease control measures, brooding technologies, protection of chicks against predation, flock separation by categories and proper feeding, among other management practices. This was a clear indicator that the chicks' mortality rate had reduced by the end of the project. Mortality rates were 44.65% and 13.57% respectively, for the periods before and after the end of the project.

Survivability rate was computed as: $\frac{\text{Average number ofchicks at weaning stage}}{\text{Average number of chicks hatched}} \times 100$

Table 4 shows the condition of the chicken houses before and after the project.

Table 4: Housing standards and management practices

Management practice	Before project		After the project	
	Proportion	Std. Err	Proportion	Std. Err.
Condition of chicken house	Poor – 0.78	0.07	Poor – 0.00	0.00
	Good – 0.22	0.07	Good – 1.00	0.00
Training on housing management	No – 0.78	0.07	No – 0.02	0.03
	Yes – 0.22	0.07	Yes – 0.98	0.03

Source; Own computation, 2016

The results revealed that only 22.5% of the project farmers kept their IC houses in good condition while 77.5% of the farmers had poor IC housing and poor conditions. However, by the end of the project, all the farmers had improved their IC houses, keeping them clean and in overall good condition. The improvements were attributed to the training of farmers by the project team on how to construct and manage their poultry housing facilities. The training was broad based and had also covered the relationships between the condition of the poultry house with biosecurity and disease control issues, and the mortality rate of birds. The poor condition of poultry houses before the project was attributed to lack of knowledge and training on housing management, and failure to understand the consequences of poor and dirty housing conditions. Upon the training, the post-project results demonstrated that all the farmers within the group had maintained good conditions of their IC housing facility and the largest proportion were cleaning their chicken houses daily.

The results shown in Table 5 and Figure 2 below illustrated the frequency of cleaning the IC housing facility. Before the project, majority (57.5%) of the farmers never cleaned their housing facilities. A few (2.5%) farmers cleaned the facility once per week, 12.5% cleaned twice per week and only 7.5% cleaned on daily basis. Post-project results showed that majority (35%) of the farmers cleaned their chicken houses on daily basis, a major improvement compared to the pre-project period. A significant proportion (27.5%) of farmers cleaned twice a week, 22.5% three times a week while 10% cleaned four times a week. Only a mere 5% of the target farmers cleaned the chicken house once a week. The notable commitment to clean their poultry houses on frequent basis post-project was attributed to the farmer training undertaken by the project researchers with emphasis on importance of bio-security in chicken management and housing. Maintenance of hygiene and sanitation in chicken housing was underscored, including the use of disinfectants. This was an essential husbandry practice in disease control for the birds and for production of bio-safe poultry products.

Table 5: Frequency of cleaning the IC housing facility

Frequency of cleaning IC housing per week		Proportion	Std. Err.
Number of times cleaned housing facility before project			
	0	0.58	0.08
	1	0.23	0.07
	2	0.13	0.05
	7	0.08	0.04
Number of times cleaned housing facility after project			
	1	0.05	0.04
	2	0.28	0.07
	3	0.23	0.07
	4	0.10	0.05
	7	0.35	0.08

Source; Own computation, 2016

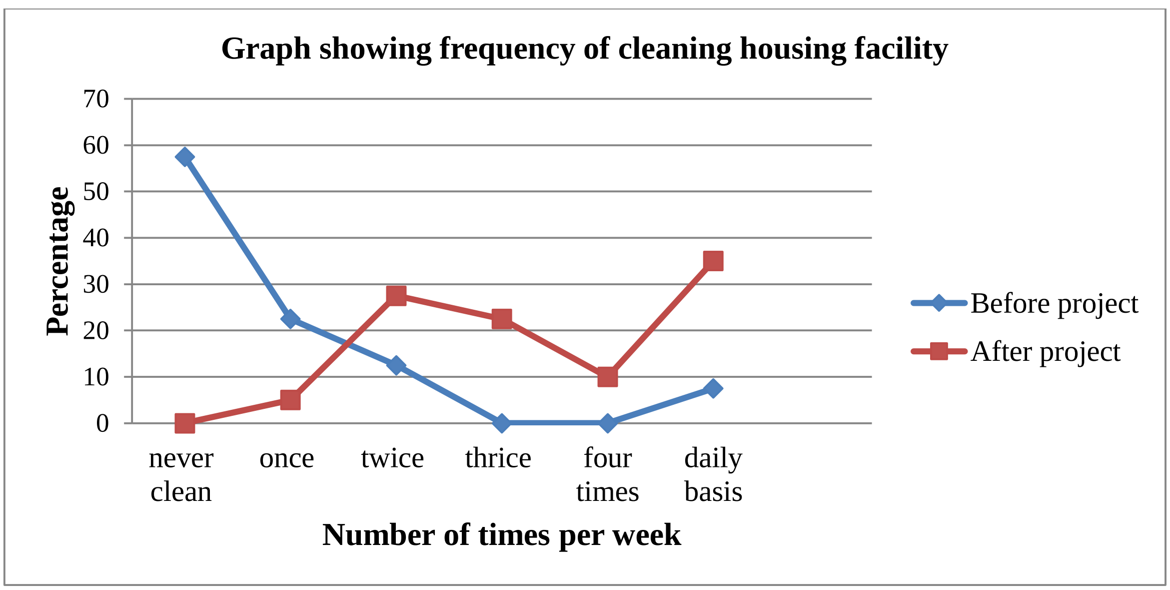


Figure 2: Trends on frequency of cleaning the housing facility

Table 6 and Figure 3 illustrate the use of brooders among the project farmers. The results demonstrated that before the project, majority (85%) of the farmers did not utilize brooders in rearing their chicks. However, 32.5% of the farmers post-project had one brooder each, 10% had four brooders and 2.5% had five brooders for rearing their chicks, depending on the number of chicks.

Table 6: Diffusion of brooding technologies among the farmer groups

Description	Proportion	Std. Err.
Brooders before the project		
0	0.85	0.06
1	0.1	0.05
4	0.03	0.03
5	0.03	0.03
Brooders after the project		
0	0.53	0.08
1	0.33	0.08
2	0.03	0.03
4	0.10	0.05
5	0.03	0.03
Type of brooders		
None	0.55	0.08
Carton box brooders	0.23	0.07
Wire-mesh brooders	0.23	0.07

Source; Own computation, 2016

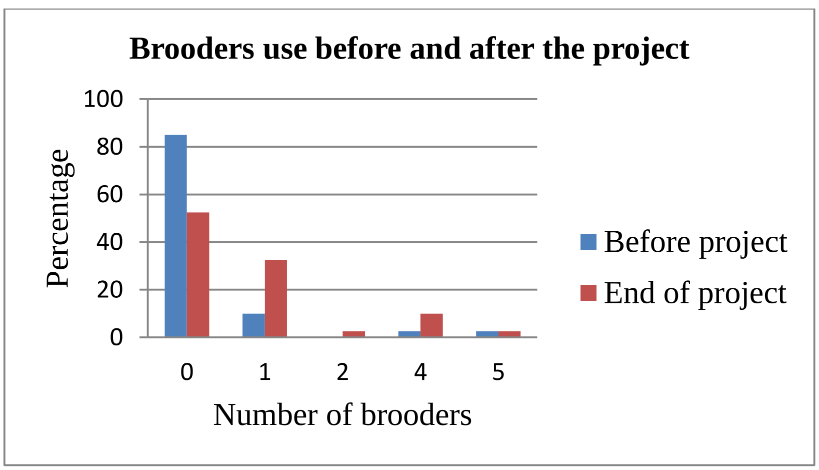
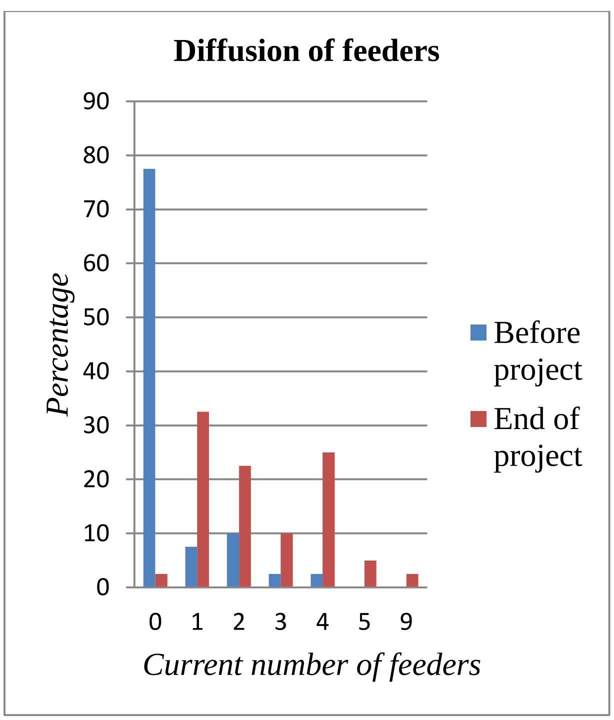


Figure 3: Use of brooders before and after the project

As an appropriate strategy, the project stakeholders disseminated 3 types of brooders to the respective farmer groups and trained on their use. The evaluation results from the table and chart above revealed that by the end of the project, 47.5% of farmers had adopted the brooding technologies. This was as a result of the training and demonstration of their importance. It was further noted that carton boxes and wire mesh were the most preferred types of materials for fabricating the brooders.

Figure 4 shows the usage of feeders and drinkers by the farmers within the group. Before the project, a big majority (77.5%) of the farmers did not have feeders and drinkers. Out of the 22.5% who had, 10% had 2 feeders in their poultry housing facility. Similarly, out of the 22.5% who had drinkers, 12.5% had only one drinker. With the project intervention, farmers in these groups received one feeder and one drinker, each. They were also trained on how to maintain them through regular cleaning and how to use them depending on the flock ration.

At the end of the project, the evaluation results revealed that 97.5% of the farmers had feeders and drinkers in their poultry houses, with majority having at least one feeder and one drinker. It is notable that out of those farmers with these facilities, a sizeable number (25%) had 4 feeders while 22.5% had 4 drinkers. This highlighted the positive impact achieved, in that farmers had perceived and responded positively towards increasing the number of these equipments, so as to enhance chicken productivity.



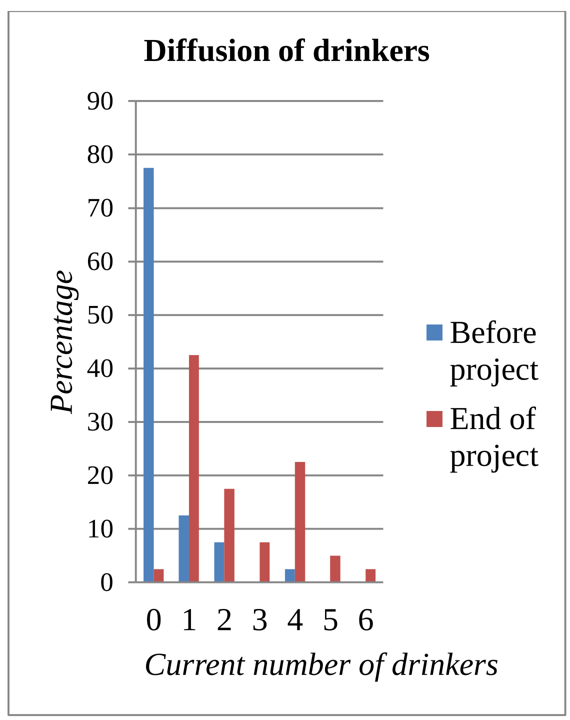


Figure 4: Diffusion of appropriate feeders and drinkers among the group farmers

Table 7 shows that majority of the farmers did not vaccinate their indigenous chicken before the project period. Only 15% of the group farmers followed the vaccination schedule as recommended by service providers. However, through field demonstrations and workshops organized by the project stakeholders, farmers were trained on how to carry out the required disease control practices using prophylactic methods, particularly vaccinations. They were also trained on the various symptoms of common poultry diseases. By the end of the project, majority of the farmers reported they knew how to identify symptoms of diseases that were likely to cause mortality in chicken and knew the appropriate measures to take. As a result of the trainings, 97.5% of the group farmers indicated they had been vaccinating their flocks post-project.

Table 7: Vaccination and disease control practices

Variable	Mean	Std. Dev.	Min	Max
Vaccination before the project	0.15	0.36	0	1
Vaccination after the project	0.98	0.22	0	1
Vaccinator before the project	0.23	0.58	0	2
Vaccinator after the project	1.30	0.52	0	2
Mortality before the project	5.13	2.40	0	10
Mortality after the project	1.85	1.94	0	7

Source; Own computation, 2016

Results from table 8 showed that before the alluded to project, only a very small percentage (2.5%) of the farmers had accessed training on feed formulation. They nevertheless acknowledged they had never put the skills into practice. They were incapacitated by lack of practice and requisite facilities for the exercise. However, all the group farmers were trained by the current project on how to carry out feed formulation, mixing, and supplementation, as a key intervention for improved nutrition and feeding of their chicken.

Table 8: Feed formulation and supplementation technology

Variable/Activity	Mean	Std. Dev.	Min	Max
Training on feed formulation before project	0.03	0.16	0	1
Training on feed formulation during project	1	0	1	1
Ability to carry out feed mixing before project	0.03	0.16	0	1
Ability to carry out feed mixing after project	1	0	1	1
Practicing feed mixing before the project	0	0	0	0
Practicing feed mixing after the project	1.53	0.88	1	3
Awareness on feed mixture technology before project	0.025	0.1581	0	1
Awareness on feed mixture technology after project	1	0	1	1

Following the procedure and ingredients ratios	1	0	1	1

Source; Own computation, 2016

Several practical demonstrations by the current project stakeholders were conducted to ensure that farmers followed the correct procedure while formulating and mixing feeds. The farmers communally used fabricated feed mixers provided by the project to mix the supplementation diets and then shared out the feed among themselves. This strategy addressed the previously existing problem of farmers who had no knowledge and pertinent equipment to mix feeds. Conducting the exercise as a group further benefited the farmers through cost sharing among themselves when purchasing any required ingredients.

Results in Table 9 revealed that before the project, farmers used to supplement their IC only once a day. They used single ingredients, mainly some grains or kitchen waste thrown at the birds. However, the project intervened and farmers were trained on formulation and mixing of balanced diets as indicated above, to supplement their birds. They mainly reared their IC through scavenging which could not adequately provide the required nutrients for high productivity without supplementation. At the end of the project, farmers in these groups were supplementing their flock twice per day with use of mixed, balanced rations. A large part of the rations comprised of grains mainly sorghum (for energy) and sunflower seed (for protein) from their farms. The farmers were trained on agronomic practices of growing these locally adapted crops by the project and had obtained good harvests for use as food and feed. This was therefore a good indicator that at the end of the project, farmers were in an enabling position to meet the nutritional requirements for their flocks, thereby increasing productivity.

Table 9: Supplementation of the IC flock

Variable	Mean	Std. Err.	Min	Max
No. of times supplementing flock before project	0.53	0.55	0	2
No. of times supplementing flock after project	1.8	0.69	0	3
Form of supplements before the project	0.85	0.95	0	2
Form of supplements after the project	0.98	0.16	0	1

Source; Own computation, 2016

CONCLUSION AND POLICY IMPLICATIONS

The current study evaluated participatory technology transfer and impact in poultry production and marketing. The significant impact from the study highlighted the importance and effectiveness of participatory technology development and transfer methods when working with rural communities. Such methods provide for faster and more sustainable gains in technology adoption, improved farm productivity and incomes, hence improved livelihoods. It is therefore recommend that policies should be formulated to strengthen participatory dissemination of improved poultry production technologies. Enhancing infrastructure and deploying more extension agents would be a significant step to facilitate effective training and extension services, and viable uptake of agricultural and livestock technologies. Additionally, farmers should put more focus on collective action by forming more Common Interest Groups (CIGs) to facilitate effective engagement with stakeholders for production and marketing in the poultry industry.

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2.Parallel Session 1: Crop Management, Biotechnology and Climate Change

2.1 Evaluation of seed quality and phenotypic characteristics of jute mallow (Corchorus olitorius) accessions from north rift region, Kenya

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ABSTRACT

Jute mallow (*Corchorus olitorius*) vegetable production in North rift region is low due to many reasons, one of them being poor quality seeds. Yields of crop has remained low 2-4 tons/ha/annum compared to expected yield of 5-8 tons/ha/annum. Farmers use much as 7kg/ha seed instead of 5kg/ha which is recommended for a density of 250 000 plants/ha that is 40% extra seed. The objective of study was to examine the seed quality

of Jute mallow accessions used by farmers at planting and evaluate their morphological diversity. A survey was conducted in North Rift region areas of Iten, Eldoret, Kapsabet, Kitale, Kapenguria, and Kenya Seed Company when farmers were asked about the husbandry of the crop. During the survey, some seeds were collected for quality tests on purity, germination and vigor using ISTA (2004) procedures. Seed sub-samples were then planted in green house and phenotypic characteristics recorded and data analyzed using GENSTAT package. The survey results showed 80% of the farmers growing jute mallow for seed were middle and old age people and 92% were females. Only 14% farmers were trained on vegetable seed production and agronomy. Education level analysis showed 54% of farmers had not attended school. Seed germination for the region was 57% that was below the quality standard of 60%. The phenotypic characterization showed diversity among the accessions with four clusters out namely: Green Early Maturing Short, Brown Early Maturing Short, Green Late Maturing Tall and Brown Late Maturing Tall. It was concluded that seed grown by farmers in North rift region is of poor seed quality and exhibit diversity. It's recommended that purification be made to improve on genetic constitution of the accessions and proper post harvest handling of the seeds be practiced to improve seed quality.
Key words: Indigenous, Vegetable.

INTRODUCTION

Jute mallow (*Corchoru olitorius*) vegetables are an integral part of obtaining nutritional security as they are a source of important nutrients essential for the good health (WHO, 2003). Jute mallow is noted for its important contribution to diet by supplying nutrients and rendering food more palatable (Grubben, 2004). In Kenya, there is ample production potential of Jute mallow not only to meet the growing demand for the domestic use requirement, but also produce surplus for export (K'opondo *et al*., 2005). *C. olitorius* is reported to be demulcent, deobstruent, diuretic, lactagogue, purgative, and tonic (Ayodele, 2005). It can meet major protein-calorific nutritional needs especially in children, sick, elderly and both expectant and lactating mothers in the rural areas (Smith and Eyzaguirre, 2007). Cooked leaves form a mucilaginous substance that has a character that is highly appreciated especially in areas where people depend on rather coarse food such as millets (Maundu, 1997). Jew's mallow leaves are normally mixed with cowpeas to reduce their coarseness or to neutralize the bitter taste in *Crotalaria brevidens* (Abukutsa-Onyango, 2004). Currently, there is no good quality seed of the vegetable crop from the breeders to the farmers (Ndinya, 2005). Production of high quality seeds has not been practiced in many of the African leafy vegetables (Abukutsa-Onyango, 2002). Farmers have been getting re-cycled planting seed of *Corchorus olitorius* every season from the local markets and farms whose potential is not assured (Okongo, 2005). Yields of crop has remained low 2-4 tons/ha/annum compared to expected yield of 5-8 tons per ha per annum (KARI, 2009), and the major constraints has been use of poor quality seeds which forces farmers to use as much as 7kg/ha instead of 5kg/ha of seed required for a density of 250 000 plants/ha, which amounts to 40% extra seed (MOA, 2009). The use of good quality seed has helped to raise yields (Amarjit, 1995). Also seeds with assured quality can be expected to respond to best agronomic practices and other inputs and increase yield in the expected manner (Bhattacharjee *et al.,* 2000) For example in India good quality seed and use of fertilizer increased wheat production from 12 million tons to 31.3 million tons over a short period of ten years (Feistrizer, 1975). Characterizations of different types of plant resources within and across accessions have been increasing in the last years (Bhattarai *et al.,* 2010). These have followed theoretical basis for inferring genetic diversity for the purpose of both breeding and conservation strategies in their identification (Akoroda, 1995). Despite increased importance of characterization in plant resources; there is scarce information about analysis of this type of data (Beebe, *et al.,* 2000). To fill such a gap of information, research needs to be done to identify diversity of accessions and the parameters for specific plant (Drossou, *et al.,* 2004). Surveys conducted in Kenya show that 50% of the people live below poverty line and live on less than one dollar a day (AICAD, 2003). To try and solve this problem, improved production and sale of vegetables like Jute mallow can play an important role in improving food security, health and general rural livelihoods (Fondio and Grubben, 2004).

Importance of Jute mallow

Corchorus olitorius is not usually eaten on its own but along other main meals as side dish (Chweya, 1985). The dark green leaves have varying proportions of Calcium, Iron, carotene, vitamin C and proteins required for good health (Schippers, 2002). Research has also shown they are nutritionally superior to exotic in many nutrients as they contain higher amounts of phosphorus, zinc, iodine, fluorine and vitamin B (Yebpella, *et al*, 2010). To avoid loosing such useful micro-elements it would be best to boil the 'soup' for as short as possible or steaming the produce would be much better (Chandha and Oluoch, 2003). The crop is a folk remedy for aches and pains, dysentery, enteritis, fever, pectoral pains, and tumors (Keller, 2004). Ayurvedics use the leaves for ascites, piles, tumors, cystitis, dysuria, fever, and gonorrhea (Kokwaro, 1990). The cold infusion is said to restore the appetite and strength of user. These vegetables fetch good prices in the market (Shiundu and Oniang'o, 2007). The expansion of production of these vegetables continues to be hampered by lack of a reliable source of planting materials and technical information (Ngoze and Okoko, 2005). The objective of study was to examine the seed quality of Jute mallow accessions used by farmers at planting and evaluate their morphological diversity.

MATERIALS AND METHODS

Survey and Jute mallow plant material collection for research.

A survey was conducted in North Rift region areas of Iten, Eldoret, Kapsabet, Kitale, Kapenguria, and Kenya Seed Company when farmers were asked about the husbandry of the crop and *C. olitorius* seed samples simultaneously collected. A sample size of 500 farmers in the region was visited by use of stratified random sampling method. The information collected using a structured questionnaire included age, sex, education background and seed and agronomy training of each farmer. The seed samples collected were then well-labeled and taken to the University of Eldoret seed laboratory for quality tests as per ISTA, (2004) procedures. Some seed sub-sample was thereafter grown in the green house for diversity evaluation.

Seed testing as per ISTA, 2004

Analytical purity test

Jute Mallow collected vegetable seeds were mixed well by passing through a seed divider several times and subsequently reconstituting them. The sub-samples for each source were obtained by successively halving the sub-sample until sample of required weight was got. Working samples of 15 grams were taken. Weight was taken for each sample and recorded. The working samples were placed on a purity work board and meticulously examined and separated to determine; seed purity. Weights of each group were separated and their percentages worked out from their initial weight of each sample (15 g) and results reported.

Germination test

Four replicates of 100 random seeds were obtained from the pure seed sample using a vacuum seed counter (with 100 holes) and placed on moistened filter paper inside a Petri dish, ensuring the seeds were sufficiently spaced. Seeds were placed in growth chamber set at 30°C temperature. Evaluation of germination was done with 1st count on 3rd day and last count on 5th day and recorded as follows: Normal and abnormal seedlings and dead seeds.

Electrical conductivity (Seed vigor) test

Distilled water of 250 ml was measured and put in 24 well labeled flasks and covered with aluminum foil to control any contamination. Other 2 flasks of distilled water of 250 ml was each set aside as control and covered with aluminum foil. The flasks were put on bench for 24 hrs at room temperature (20-23°C). Jute mallow seeds (50) were added to each flask and left to soak for 24 hours. The soaked seeds was then swirled gently for 10-15 seconds and conductivity (μ S $cm^{-1}g^{-1}$) of soak water was measured upon meter showing constant reading. Between measurements, dip cell was rinsed twice in distilled water and dried using clean dry paper towels. The conductivity per gram of seed weight for each replicate was calculated after accounting for the background conductivity of the original water and the average of the four replicates provided the seed lot result.

Phenotypic characterization of *Corchorus olitorius* at the green house

The experiment was done in the green house. Boxes measuring 50 cm x 30 cm x 30 cm were filled with well mixed naturally fertile well – drained, friable, sandy clay soil of Ferro - orthic acrisol with an average pH of 5.0 and seed samples from markets centers, farms and Kenya Seed Company planted. At the green house, boxes were laid out using randomized complete block design each seed source with three replications in three blocks. Phenotypic characteristics from each sample were done and recorded as follows:

Plant height: Five random plants from the net plot (box) were measured for stem height from the base to the tip at harvesting time.
Number of pods per plant: Five plants were sampled, from the net plot at harvest and the average number of pods determined.
Leaf petiole length: Five plant leaf petioles were sampled, from the net plot at harvest and the lengths determined.
Leaf Lamina: Five plants were sampled, from the net plot at harvest and leaf lamina shape recorded, its length and width determined.
Leaf Serration: Five plants were sampled, from the net plot at harvest and the direction of serration recorded.
Leaf tip shape: Five plants were sampled, from the net plot at harvest and the leaf tip shape recorded.
Leaf color: Five plants were sampled, from net plot at harvest and the leaf color recorded.
Flower characteristics: Five plants were sampled, from the net plot at harvest and the flower shape, color, number of sepals and its length and width recorded or determined.
Fruit characteristics: Five plants were sampled, from the net plot at harvest and the fruits' shape recorded and its length and width determined.
Seeds per pod: Five plants were sampled, from the net plot at harvest and number of seeds per pod determined.

RESULTS

Survey and Jute mallow seed production

Most of the farmers growing Jute mallow vegetable for seed were middle and old age people accounting for over 80% of total farmers interviewed. Men were missing in Jute mallow seed business with only 8% present in Eldoret and Kitale at the middle age (41-59 years) making female dominate with 92% in its production in the region.

Training of farmers

Results on training of farmers showed that on average only 14% of all the total farmers interviewed in North Rift region had been trained on agronomy, crop protection and seed production aspects of Jute mallow. The remaining 86% farmers were doing Jute mallow seed production without any form of training at all. The trained farmers per area are: Kitale-24% (highest in the region), Eldoret-16%, Kapsabet-12%, Iten-11% and Kapenguria-8% (lowest).

Education level of farmers

Education level analysis showed that 54% of the farmers had not attended school. This means that over half of the farmers doing seed production are illiterate that is they cannot read and write and so cannot prepare or use farm records. The low level of education could be one of the hindrances to use of farm records in areas of North Rift region as a tool for seed quality improvement but rely on their memories for information storage.

Seed supply outlets of Jute mallow

The farmers interviewed showed 98% depended on the informal seed supply sector for their Jute mallow seed, while only 2% depended on the formal seed supply sector. It was also observed that 69% of farmers use own saved seed for planting, while 24% got Jute mallow seed from neighbors, 5% from Informal seed sector (local market) and only 2% from Formal seed sector market.

Fertilizer use for quality crop

Fertilizer use showed 66% of the farmers interviewed do not use any fertilizer during the production of Jute mallow. Those farmers who apply fertilizer at planting do not top dress as required for improving quality of seed and crop that meet market grade /requirements.

Method of planting Jute mallow

During the planting of Jute mallow, 73% farmers broadcasting seed, thereby using higher seed rates as compared to 27% drilling in lines. It was observed that only 19% farmers use the optimum seed rate of 5 kg/ha, 10% farmers under use seed rate - (3% use 3 kg/ha and 7% use 7 kg/ha) as opposed to 71% of farmers that over use the seed rate - (29% use 6 kg/ha and 42% use 7 kg/ha).

Indicators of Jute mallow pod maturity and harvesting method

Majority of the farmers (84%) indicated that pod has matured when it turns from green color to tan indicating seed has reached harvest maturity, or the stage of seed development when it has dried to a moisture level at which it can be harvested without appreciable risk of mechanical damage. The method of harvesting Jute mallow seed by farmers involves cutting the whole plant as done by 75% of the farmers as opposed to 25% farmers who chose to hand pluck pods that have matured.

Handling of Jute mallow seed from harvest to storage

On the method of Jute mallow seed extraction, 98% farmers extracted their seed from pods by beating with sticks. In Jute mallow seed drying, it was observed that all the farmers (100%) dry their Jute mallow seed in direct sunlight as opposed to drying in shade for 4 days and only 1 day in sunlight. In seed storage, most of farmers (83%) store their Jute mallow seeds in pots/tins and plastic/synthetic. On storage duration, half of the farmers (53%) had saved their seeds for over 5years. Those that had stored for 4years was 23%, 3years was 20%, 2years was 15%) and those stored for 1year was 12%.

Seed quality testing of Jute mallow

Analytical purity results

The processed seed from Kenya Seed Company had the highest purity percentage (100%) compared with seed from both the markets (99%) and farms (98%). Purity analysis results showed that all the Jute mallow vegetable seed from the region were of superior quality as per ISTA (2004) procedures stating seed quality of above 98% purity is considered of superior quality.

Germination results

Seed germination for the North rift region was 57%, the highest germination was from processed source; Kenya Seed Company (86%) and the lowest germination was from farms source with 53%, though germination from markets were equally low (54%). Compared to ISTA, (2004) minimum Jute mallow seed germination requirement of 60%, Jute mallow seeds from North rift region do not meet this minimum standard.

Radicle seedlings (normal and abnormal seedlings), result showed Kenya Seed Company had highest seedling emergence (88%) and Kapsabet farms (37%) had lowest compared with markets (59%) and farms (58%), (table 1). Also though seedling emergence of Kitale farms (73%) and Eldoret farms (72%) were high, germination percentage were reduced to Kitale (67%) and Eldoret (67%) by high number of abnormal seedlings by 6% (Kitale farms) and 6% (Eldoret farms). This trend was also observed in seed from other areas of North Rift region. On average, over half of seeds from North Rift region germinated on the 1st day.

Electrical Conductivity of Jute mallow (Seed Vigor)

The conductivity results showed that all seeds from the North rift were of high vigor. Kenya Seed Company had the leachate conductivity of 2.69 $\mu Scm^{-1}g^{-1}$ (lowest) and Kapsabet farms had the Electrical conductivity of 7.09 $\mu Scm^{-1}g^{-1}$ (highest) though so, all seeds were still of good quality as they were within range of blow 10 $\mu Scm^{-1}g^{-1}$ level, within high vigor as per ISTA, (2004).

Phenotypic characterization of Jute mallow

Phenotypic characterization showed diversity among the accessions with four varietal clusters out namely: Green Early Maturing Short (GEMS), Brown Early Maturing Short (BEMS), Green Late Maturing Tall (GLMT), and Brown Late Maturing Tall (BLMT).

Plant height measurements (cm) at harvesting

C. olitorius plant height showed significant differences (p=0.001) for sources and locations. There was no interaction between variety and locations. The early maturing plants were short (28 cm) or dwarf or less than 50 cm (table 2). GEMS and BEMS were same in height (28 cm) and differentiated by stem color. GLMT and (BLMT) (82 cm) were tall and differentiated by color.

Pod count

C. olitorius pod count results showed no significant differences (p=0.001) for source and locations. GEMS and BEMS pod count per plant showed same number of pods (6), likewise to GLMT and BLMT with 17 pods per plant, though BEMS highest was 14 pods from Kenya Seed Company (table 3) and stem color could only differentiate them.

Leaf measurements

i) Petiole length

C. olitorius petiole length analysis showed no significant difference (p= 0.001) for sources and locations, nor between varieties. The GEMS and BEMS from markets and farms had same length of 1.3 cm and Kenya Seed Company had petiole length of 1.2 cm. GLMT and BLMT both from market and farm had same petiole length of 1.7 cm (table 4).

ii) Leaf lamina

C. olitorius leaf lamina shape was lanceolate with no significant difference (p=0.001) in leaf width. The late maturing variety had leaf width of 2.8 cm while early maturing variety had 2.6 cm (table 5). There was significant difference in leaf lengths (p=0.001) across varieties. Leaf length of late maturing (8.6 cm) was longer than early maturing of (6.0 cm).

iii) Leaf serration.

All GEMS, BEMS, GLMT and BLMT had serration present facing leaf apex.

iv) Leaf tip.

All GEMS, BEMS, GLMT, and BLMT leaf tips had acute shape.

v) Leaf color.

All GEMS, BEMS, GLMT, and BLMT leaves were green.

Flower characteristics.

All the GEMS, BEMS, GLMT, and BLMT flowers shapes were solitary and small and were in opposite side to the leaves, Color being yellow, Sepals were 5 and narrow. *C. olitorius* flower measurements showed no significant difference (p=0.001) for varieties. The GEMS, GLMT, BEMS, and BLMT had same flower width and length (1, 1.2 cm) (table 6).

Fruit characteristics

i) Size:

C. olitorius fruit width and length measurements showed no significant difference (p=0.001) for varieties. The late maturing (1.3 cm) are significantly same in width as early maturing (1.2 cm). There was variation for late maturing (3.9 cm) and early maturing (3.7 cm) in reference to fruit length (table 7).

ii) Shape:

All GEMS, BEMS, GLMT, and BLMT had fruits that were cylindrical, 10 ridged, dehiscing by 5 with traverse septa between the seeds.

Seed characteristics

All GEMS, BEMS, GLMT and BLMT had pyramidal shape length of 1 mm and dark grey in color.

DISCUSSIONS

Survey and seed collection

The seed survey showed that most of the farmers growing Jute mallow vegetable were middle age (41-59 years) and old (60 years and over), accounting for over 80% of the total farmers interviewed meaning that Jute mallow growing was not done by young generation as observed also by Abukutsa- Onyango, (2002). In North Rift region, it was observed that men do not engage in growing Jute mallow crop in the farms which they consider best women work. Different scenario was observed at market where some 8% male practiced Jute mallow seed business in Eldoret and Kitale markets and were only at the middle age (41-59 years). Few farmers (14%) in North Rift region had been trained on vegetable seed production and agronomy, leaving 86% farmers doing vegetable seed production without having attended any training. This showed that they were using their own indigenous knowledge in Jute mallow seed production. There were 69% farmers having undergone at least one kind of training on the crop. No farmer had attended four or more trainings in the whole of North Rift region. This could be one of the reasons why Jute mallow yield has remained low at 2-4 tons/ha/annum as compared to the expected yield of up to 5-8 tons/ha/annum concurring with findings put forward by MOA, (2009). Education level showed that few farmers (46%) had attended school meaning that over half of the farmers (54%) doing seed production were illiterate i.e. could not read and write, so cannot prepare or use farm records to know their level of quality seed production, but relied on their memories to store information. Low level of education could be one of the hindrances to use of farm records tool in North Rift region. This in turn could have contributed to low quality of Jute mallow seed production in the region by farmers. Such decline in seed quality and crop productivity therefore reduces profits, which concurs with what Ellis and Roberts, (1981) put forward that low quality seeds leads to non acceptance of the vegetable by consumers because of low quality product, supporting also what George, (1985,1999) found out.

Analytical purity of Jute mallow seeds

Analytical purity showed that Kenya Seed Company had the highest purity percentage (100%) compared with seed from the regions, markets and farms. Iten market and

Eldoret farms had the lowest purity (98%). According to ISTA, (2004), the quality of seed analysis is considered superior if purity percentage is above 98% meaning that all the Jute vegetable seed from region were of superior quality. Though so, Louwaars, (1994) observed that purity *per se* is not gauge of good quality seed but a sum total of several seed attributes, needing more tests to ascertain seed quality.

Germination of Jute mallow seeds

Germination of Jute mallow seed from Kenya Seed Company (86%) was highest and the lowest germination was from Kapsabet farms (32%). This means that Kenya Seed Company Jute mallow seed would do better in field than all of the seeds from various sources analyzed. The North rift region results analysis showed low germination of 57%, though some of its Jute mallow seed sources like Kenya Seed Company was high (86%). Compared to ISTA, (2004), which requires Jute mallow seeds germination to have minimum germination percentage of 60%, North Rift region had its Jute mallow germination at 57%, thereby not meeting required minimum standard for it to be used as seed. Jute mallow seeds from Kenya Seed Company had high vigor (88%) in terms of emergence as compared with low Jute mallow seed emergence from other seed sources analyzed in North Rift region. This trend could be expected to perform the same in the field if these seeds were planted on the soils in farm. This low seedling emergence could be contributing to low yields and supports what was observed by Peacock and Hawkins, (1970) and Franzern *et a*l. (1996).

Electrical conductivity (seed vigor) of Jute mallow seeds

Kenya Seed Company had the lower leachate conductivity of 2.69 $\mu Scm^{-1}g^{-1}$ meaning that the seeds were of high vigor. Seeds from North Rift region had equally low leachate conductivity of 4.50$\mu Scm^{-1}g^{-1}$. Kapsabet farms had higher Electrical conductivity of 7.09 $\mu Scm^{-1}g^{-1}$ though the seeds were still of good quality. This means that though seeds from North Rift region were of high vigor, further tests on seeds are needed to ascertain why there were low yield in the region. This supports observations made by Amarjit, (1995) recommending several seed tests needed to be done to find out why seeds showed poor performance in field yet laboratory results showed high seed vigor.

Jute mallow phenotypic characterization

During phenotypic characterization four varietal clusters came out based on color, maturity and height as follows: Green Early Maturing Short, Brown Early Maturing Short, Green Late Maturing Tall and Brown Late Maturing Tall. Such observation was also found out in Nigeria by Epenhuijsen, (1974), though he only found two varieties and named them in Nigerian local language as *Amugbadu*, and *Oniyaya* and acknowledges that in reality there exists diversity in Jute mallow grown by farmers.

Early maturing short (GEMS and BEMS) varietal cluster characteristics

The early maturing *C. olitorius* varietal clusters were short or dwarf (less than 50cm).This meant that the GEMS (28 cm) and BEMS (29 cm) had no significant difference in plant height and only differentiated by stem color during selection to different varieties. GEMS pod counts per plant were same for seed sources (6 pods), Kenya Seed Company had highest with 14 pods and the lowest was Kapenguria market (4 pods). This showed that Kenya Seed Company could produce more seed yield per unit area than from farm or market thereby increasing profit margins of farmers. The BEMS pod count per plant showed no significant difference between varieties, the highest was 6 pods and the lowest was 4 pods, leaving the average of the North Rift region BEMS with 6 pods per plant. Farmers could plant BEMS or GEMS as both were easily found within their areas, though if Kenya Seed Company could make their seed (GEMS) readily available to the farmers they would benefit more in terms of increased seed yield and profit from sales of Jute mallow. From the Petiole length analysis it was observed that there was no significant difference between varieties. On average GEMS and BEMS Petiole length was 1.2 cm and could only be differentiated by their stem colors. The GEMS and BEMS Leaf lamina shape was lanceolate measuring 5.5 cm length by 2.5 cm width and in alternate positions. The Leaf serration of both GEMS and BEMS were present and facing leaf apex. The leaf tip was acute in shape. The leaf color was green. The flowers were solitary, yellow, with 5 narrow sepals.

Late maturing tall varietal cluster characteristics

Corchorus olitorius GLMT and BLMT varietal clusters showed significant difference in plant height with 95 cm being the tallest plant height and with 75cm being shortest and an average of 85cm. There were no tall plants in Kenya Seed Company, which indicated that it had been purified to remove BLMT and GLMT varieties. The farmers could plant any of the varieties and get the required crop for sale during the planting season as both would give same output. There was no significant difference for pods between locations with GLMT and BLMT plants having pod count per plant at 18 pods, with lowest pod count per plant being 16 pods. Kenya Seed Company had no late maturing plants. Both GLMT and BLMT had leaf length at 1.7cm and could only be differentiated by their stem colors. The leaf lamina shapes for both GLMT and BLMT were lanceolate and in alternate position but varied in length sizes where GLMT was longer. Both types had leaf serration which were facing leaf apex with its leaf tips of acute shape. The flowers for both varieties were yellow, solitary, in opposite to leaves, same in size and had 5 narrow sepals. Both varieties had same sized fruit with cylindrical shape having 10 ridges in each fruit dehiscing by 5, with traverse septa between seeds. There were 100 seeds per capsule for both GLMT and BLMT. For both varieties, the seed color was dark grey with pyramidal shape. These seeds were 1 cm in length and had a seed weight of 400 seeds per gram.

TABLES

Table 1: Germination and Emergence percentage of Jute mallow from various sources

Source	Location	Standard germination test			
		% Dead seeds	% Abnormal seedlings	% Normal seedlings	% Emergence of radicle
	Iten market	40	6	54	60
	Eldoret market	29	5	66	71
Markets	Kapsabet market	42	4	54	58
	Kitale market	46	5	49	54
	Kapenguria market	47	5	48	53
	Average of markets	41	5	54	59
Processd	Kenya Seed Company	12	2	86	88
	Kitale farms	27	6	67	73
	Eldoret farms	28	6	66	72
Farms	Iten farms	35	6	59	65
	Kapsabet farms	63	5	32	37
	Kapenguria farms	55	2	43	45
	Average of farms	42	5	53	58
N/R region mean				57	

Table 2: Mean plant height measurements (cm) at harvesting

Source	Location	Mean plant height		Mean plant height	
		GEMS	BEMS	GLMT	BLMT
Markets	Kitale	27±2.5	25±1.7	88±8	89±11.7
	Kapsabet	33±2.9	35±2.6	95±13.1	91±0.6
	Iten	28±1.5	26±1	83±6.7	80±8.5
	Kapenguria	25±1.7	24±1	75±1	72±3.2
	Eldoret	29±1.5	30±3.2	81±6.1	84±2.1
	Mean of markets	28	28	84	83
Processed	Kenya Seed Company	27±1	-	-	-
Farms	Kitale	30±2.5	32±3.1	82±3.1	78±7.2
	Iten	26±0.6	27±0.6	85±4	81±5.3
	Eldoret	30±1	31±3.8	83±7	83±5.5
	Kapsabet	29±2.5	30±2.9	90±10.4	77±4
	Kapenguria	27±1.5	28±1	83±3.5	82±7.6
	Mean of farms	28	29	84	80

Note: (-) denotes variety not present in seed from the source

Table 3: Mean pod count in numbers of Jute mallow from various sources at harvesting

Source	Location	Mean pod number		Mean pod number	
		GEMS	BEMS	GLMT	BLMT
Markets	Kitale	5±1	6±1	17±0.6	17±1
	Kapsabet	6±0.6	6	18±1.5	18±1.7
	Iten	5±1.7	5	17±0.6	17±0.6
	Kapenguria	4±0.6	4±0.6	16	16
	Eldoret	6±1	6±0.6	16±0.6	16±1
	Mean of markets	5	5	17	17
Processed	Kenya Seed Company	14±2.1	-	-	-
Farms	Kitale	5±0.6	6	18±1.5	17±1.5
	Iten	5±0.6	5±1	17±0.6	17±0.6
	Eldoret	6±0.6	6±0.6	17±0.6	18±1.5
	Kapsabet	6±0.6	6±1	17±1.2	17±0.6
	Kapenguria	5±0.6	5±0.6	17±0.6	18±0.6
	Mean of farms	5	6	17	17
Mean of North Rift region		6	6	17	17

Note: (-) denotes variety not present in seed from the source

Table 4: Mean petiole length measurements (cm) of Jute mallow varieties at harvesting

		Mean length (cm)		Mean length (cm)	
Source	Location	GEMS	BEMS	GLMT	BLMT
Markets	Kitale	1.4±1	1.3±0.1	1.8±0.1	1.7±0.2
	Kapsabet	1.3±0.1	1.3±0.1	1.7±0.1	1.7±0.1
	Iten	1.3±0.1	1.2±0.1	1.6±0.2	1.6±0.1
	Kapenguria	1.1±0.1	1.2±0.1	1.7±0.1	1.8±0.1
	Eldoret	1.4±0.1	1.3±0.1	1.8±0.1	1.7±0.1
	Mean of markets	1.3	1.3	1.7	1.7
Processed	Kenya Seed Company	1.2±0.1	-	-	-
Farms	Kitale	1.3±0.1	1.3±0.1	1.7±0.1	1.7±0.1
	Iten	1.3±0.1	1.2±0.6	1.7±0.2	1.6±0.1
	Eldoret	1.3±0.1	1.2±0.6	1.8±0.1	1.7±0.1
	Kapsabet	1.2±0.6	1.2±0.1	1.6±0.1	1.7±0.1
	Kapenguria	1.2±0.1	1.2±0.1	1.6±0.1	1.7±0.1
	Mean of farms	1.3	1.2	1.7	1.7
Mean of North Rift region		1.3	1.3	1.7	1.7

Note: (-) denotes variety not present in seed from the source

Table 5: Mean width and length measurements (cm) of Jute mallow leaf at harvesting

Measurement	Mean		Mean of early maturing	Mean		Mean of late maturing
	GEMS	BEMS		GLMT	BLMT	
Width (cm)	2.5±0.1	2.7±0.2	2.6	2.8±0.1	2.8±0.1	2.8
Length (cm)	5.5±0.4	6.5±0.5	6.0	8.4±1.1	8.8±1.2	8.6

Table 6: Mean width and length measurements (cm) of Jute mallow flower petals

Measurement	*Mean*		*Mean of early maturing*	*Mean*		*Mean of late maturing*
	GEMS	BEMS		GLMT	BLMT	
Width (cm)	1.0±0.1	1.0±0.1	1.0	1.0±0.1	1.0±0.1	1.0
Length (cm)	1.1±0.2	1.2±0.1	1.2	1.2±0.1	1.2±0.1	1.2

Table 7: Mean width and length measurements (cm) of Jute mallow fruit at harvesting

Measurement	Mean		Mean of Early Maturing	Mean		Mean of Late Maturing
	GEMS	BEMS		GLMT	BLMT	
Width (cm)	1.1±0.4	1.2±0.5	1.2	1.3±0.4	1.3±0.5	1.3
Length (cm)	3.5±0.5	3.8±0.6	3.7	3.8±0.4	3.9±0.6	3.9

CONCLUSIONS

C. olitorius seed production status showed that most farmers in the North Rift region get their seed for planting from own saved seed or neighbors where storage was in plastic tins usually stored in the open. Most farmers were illiterate as shown by low level of education, were aged and have not been trained on seed and agronomic aspects of Jute mallow.

C. olitorius seed grown by farmers in North Rift region though of high analytical purity is of poor physiological seed quality as seen from the high percentage of dead seeds. The dead seeds could be result of: - immature harvested seed, diseased seeds, poor processing methods/ storage conditions right from farms to markets. It was also concluded that seed grown by farmer's exhibit diversity. This is true because during phenotypic characterization, four varieties came out based on color, maturity and height as follows: Green Early Maturing Short, Brown Early Maturing Short, Green Late Maturing Tall and Brown Late Maturing Tall.

RECOMMENDATIONS

The government of Kenya and other Stakeholders of the seed sector e.g. Universities, Seed merchants, KARI and KEPHIS to increase trainings to seed producers either formal or informal to enhance seed quality production and proper practices of post harvest handling of seeds. This could be done through farmer field schools so that the farmers could be reached through group approach to improve on issues on seed quality production and their related agronomic practices.

The recommended seed for use by farmers is from Kenya Seed Company, Kitale having showed high purity, germination, and vigor. The rest of seed lots from North Rift region should not be used as seed for it will lead to poor yields due to its low seed quality.

It is also recommended that purification be made by breeders or seed companies to improve on genetic constitution or come-up with new varieties or improved selections.

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2.2 Morphological and Biochemical Traits of Sorghum Fostering Abiotic Stress Tolerance Superiority among Cereals: A Review

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Abstract
Sorghum (*Sorghum bicolar* L. moench) is very important for high tolerance to both abiotic and biotic stressors. The crop is amongst five most important cereals in the world contributing to food, fodder, fuel, ethanol and other industrial products like ropes and bags. Sorghum derived foods are special for weight management; they function in body sugar regulation through slower digestibility and longevity in the digestive system. The crop initially neglected, is gaining importance in the agricultural sector due to its ability to grow well and produce in poor precipitation, high soil salinity and in infertile soils. These traits enhance sorghum's potential in enhancing food security and enabling sustainable crop production in face of climate change. The unique morphological and biochemical advantages of this crop are necessary for evaluation and introduction into other important cereals. This review highlights the exceptional abiotic stress management mechanisms of sorghum, illustrating why this orphan crop should be considered as a model crop for research in understanding and addressing a biotic plant stressors in cereals for better productivity.
Keywords: Sorghum, a biotic stress, traits, reals, food security

INTRODUCTION
Sorghum is an annual cereal crop of tropical Africa origin, (Burkhart, 2007; Menz *et al.*, 2004, Peterson *et al.,* 2009). The crop was domesticated in Africa back in 3000 BC, (Burkhart, 2007). However, it has spread all over the world, with current production in Africa, China, Central America, South America, India, Australia and the United States. It is a staple food crop in sub-Saharan Africa and Asian countries, (Menz *et al.,* 2004; Ratnavathi & Patil, 2013), and used as a major source of fodder in India, china, North America and Australia, (Csrl, 2013). In United States of America, sorghum introduction was mainly for syrup production; currently it is an important source of fodder and uses in ethanol production, (Peterson *et al.,* 2009).
Sorghum grows well in a wide range of agro ecological zones (high potential to low potential lands), it is explicitly known for above average growth and productivity in marginal areas characterized by prolonged droughts, (Price *et al.,* 2005; Dalal *et al.,* 2012). Apart from abiotic stresss, some cultivars of sorghum harbor beneficial insects including: beetles and lacewings, this offers better pest management measure, (Clark, 2007).

As a staple food, sorghum is used in preparation of meals such as: porridge, biscuits, cakes and bread, (Ratnavathi & Patil, 2013; Yones *et al.,* 2016), the grains are also used in preparation of alcoholic beverages, while the other parts are used to make wall boards, and packaging materials, (Delserone, 2008). Forage sorghum cultivars are used to prepare quality silage and hay; some are chopped and fed to livestock directly or as pastures. Other sorghum cultivars are now in use for biofuel production, (Dalal *et al.*, 2012; Csrl, 2013).

Sorghum is an upright annual plant, a member of the Poaceae family. Have flat to erect leaves. The plant exhibits varying heights and maturity, this is highly dictated by the cultivar. Growth characteristics also differ due to manipulation by the environment, production resources (inputs) and cultural practices. Sorghum can be categorized into: grain sorghums (*Sorghum bicolor ssp. bicolor*), Sudan grass (*Sorghum Bicolor ssp. drummondii*) and forage sorghums (*Sorghum bicolor*), (Kearney & Peebles, 1969; Burkhart, 2007). Forage sorghums are more vegetative, taller with late maturity, Sudan grass is in between the forage sorghum and the shorter grain sorghum, and this is not always the case since there a number of taller grain sorghum. Both Sudan grass and forage sorghum are mainly used as livestock feeds, and do exhibit high regeneration, (Awad *et al.,* 2013).

Sorghum alongside other small grained cereals such as millet, are important hardy cereals for water use efficiency characteristics, enabling high tolerance to water limiting conditions. A number of Sorghum cultivars grow fast and mature within short rainfall seasons in semiarid areas. The crop has better regeneration ability after exposure to dire conditions of drought and high temperatures. The crops exhibits good growth and development in resource deficient soils. Accumulation of compatible solutes within the sorghum plant tissues is credited for efficient osmo-regulation system; this has been specifically attributed to survival in saline environments, (Csrl, 2013, Zhang *et al.,* 2014).

In general sorghum exhibits a complex interaction of both physiological and biochemical processes that synergistically enhance its ability to tolerate abiotic stressors, (Dalal *et al.,* 2012; Schittenhelm & Schroetter, 2014). The current climate change consequences of elevated frequencies of heat stress, floods and droughts are destabilizing world food production, necessitating measures in understanding the stress tolerance and adaptation mechanisms in hardy crops for their incorporation and over expression in agriculturally important crops. Sorghum provides such an avenue, (Blum, 2005; Dalal, *et al.,* 2012).

Drought tolerance

Climatic variability is a major contributor to inconsistency of crop yields, (Kang *et al.*, 2009; FAO, 2015). One important crop production factor, water is highly affected by the climate variations; this is seen in drought and flood events that incapacitate crop growth, (Trenberth, 2008). Limited water for plant growth and development is a common condition in the dry lands, (Anjum *et al.,* 2011; Dalal *et al.,* 2012), and is recently reported to advance to highly productive agro ecological zones as a result of climate change, (Dalal *et al*, 2012). Today, unexpected water shortages in important crop production zones is decreasing the total food production and increasing the challenge of food insecurity, (Shao *et al.,* 2009).

Sorghum possesses superior traits for tolerance to abiotic stressors, (Assaefa *et al.*, 2010; Csrl, 2013). Among them; Drought escape (completion of life cycle ahead of water deficit onset), as seen in early anthesis of some cultivars. Dehydration avoidance, fostered by superior soil moisture absorption of the deep roots, and reduced evapo-transpiration from leaves. The crop also demonstrates dehydration tolerance, the capacity to uphold cellular processes in low tissue water potential, (Dalal *et al.,* 2012). The leaves of sorghum have limited expansion, manipulated stomata opening, and high photosynthesis in elevated temperatures.

Generally plants are directly affected by the reduction in leaf turgor potential as a result of less water, this significantly hinder the normal functioning of cells (Jones & Turner, 1977). However, some plants have elaborate survival mechanisms, as reported by Jaleel *et al.,* (2008), upon noting increased root development of *Catharanus spp* under water stress. High evapo-transpiration needs by plants in elevated temperatures result to poor metabolism. Low soil fertility cause stunted growth to plants. Saline environments hinder plants ability to capture water even in moist soil. It is therefore very important to study stress tolerance mechanisms by plants and devise measures for their enhancement in important crops, this starts with understanding the behaviors of common abiotic stress tolerant plants, (Duan *et al.,* 2007; Mickelbart *et al.*, 2015).

Sorghum root system

Sorghum is significantly deep rooted, (Dalal *et al.,* 2012; Schittenhelm & Schroetter, 2014). The extensive root system may penetrate up to eight feet into the soil and more than three feet away from the stem; extending from 1 m to 1.6 m away from the plant as described by Assefa *et al.,* (2010). These roots enable capture of water from the subsoil (Shoemaker & Bransby, 2010). Both the seminal and nodal roots of sorghum are uniquely endowed with large vessel diameters, this is believed to affect vessel–vessel connections, and are factors in embolism and refilling as described by Johnsons *et al.*, (2013), from their work in investigating hydraulic signaling means between roots and shoots for arid plants. Root thickness, root length density, number of thick roots and root volume are factors that contribute to both water and nutrients absorption by the plant, (Ronggai *et al*., 2015).

Leaf and Stem based modification

Sorghum leaves are usually green, glossy, flat to erect, and relatively narrow; having reduced number of stomata's, hence less exposure to water loss. High epicuticular wax on sorghum leaves enhances efficient water conservation, by lowering water loss from the leaves by evapo-transpiration, (Dalal *et al.,* 2012). Wax is made up of free fatty acids, n- alkanes, steroids, aldehyde, both primary and secondary alcohols and ketones. Over 30% of water conservation by sorghum is by this wax. Cameron *et al.,* (2006), observed instances of increase in wax accumulation in tree tobacco leaves a result of inducement by dehydration stress. Similarily, Hamissou and Weibel, (2004), had initially illustrated the relationship between wax cover and plant water content, asserting a correlation of high plant water content with high wax accumulation. In their work, Shepherd and Griffiths, (2006), observed that increase in wax thickness (accumulation) in cuticle was contributed by increase in temperature and light intensity, implicating wax instances in crops to be more in dry hot conditions typical of the tropical region believed to be where sorghum was first domesticated. Accumulation of wax is controlled by a type of lipid proteins, increase in associated genes in water limiting conditions were observed by Cameroon *et al.,* (2006), these genes can be screened, isolated and studied for introgression in other crop plants. According to Shepherd & Griffiths., (2006), the wax layer on leaves creates a hydrophobic interface between the leaf tissue and the outside preventing water loss.

Leaf rolling that precede the stomata closure in high temperatures as influenced by leaf water potential together with stomatal conductance (controlled by soil moisture dependent signals**)** these are characteristics uniquely efficient in sorghum, (Amelework, 2015). The rows of motor cells along the midrib on the upper part of sorghum leaf enable rapid roll up of leaves during moisture stress. This technic is said to be evident about twelve days of exposure to water stress, Assefa *et al.,* (2010). The stem of sorghum plant is solid and dry, to succulent. The stems are light green, blue to whitish in color with a thick waxy layer. The dull colouration and wax layers contributes to reduced water loss.

Osmoregulation

In spite of the long root systems there are enzymatic mechanisms facilitated by deposition of solutes in root vacuoles, this enables attainment of an osmotic adjustment that function in increasing flow of water from the dry soils into sorghum plant. Solute accumulation and sugar storage in sorghum root and other tissues is in form of soluble solutes that are non- toxic at high cytolsolic concentration. Osmotic adjustment has a significant role in maintaining the turgor relations of plants subjected to water deficit (Jones & turner, 1977; Girma & Krieg, 1992). The lowering of osmotic potential by net solute accumulation limit water loss from leaf tissues. These solutes also function in detoxification of reactive oxygen species, stabilization of membranes and are key in maintainace of enzymes and proteins native structures. Sorghum in particular produces proline and glycinebetaine, these are osmolytes preventing cells from dehydration. Dwarf sorghum varieties are believed to synthesis more osmolytes, an indicator of higher expression of glycinebetaine and proline ecoding genes. The elevated osmotic adjustment in sorghum is believed to be acquired high selection pressure in dry areas. Sorghums, exhibiting this have slow rates of leaf senescence under water limiting condition and similarly displays, postponed leaf rolling and leaf tissue death, a contribution of the massive accumulation of compatible solutes, (Chen *et al.,* 2007).

Uptake of micro elements to boost resilience to water stress in saline conditions

Absorption and deposition of silicon in sorghum roots has been known to reduce Na^+ toxicity in sorghum and similarly enhanced water uptake from dry soils, (Lux et al., 2003). Yin *et al.,* (2015) found silicon amendment in soil causing reduced uptake of Na^+ by the sorghum roots, this enables reduced salinity stress to the plant. There are cases of storage of active ions in vacuoles and deposition in tonoplast preventing cell toxicity. It had also been illustrated earlier by Yin *et al.,* (2014), in his description of silicon mediated enhanced water uptake by sorghum roots in dry conditions.

Uptake and deposition of silica in stems and roots of the plants in poaceae family led to development of highly branched roots, this had been outlined by Hattori *et al.,* (2003) as one that advantageously benefited such plants promoting their survival in dry soils. Similarly, silica enhanced rapid root elongation. According to Lux *et al.,* (2002), who observed higher aggregation of silica in drought tolerant sorghum, drought tolerance could also be contributed by the microelement. In saline environment, sorghum is able to undergo root cells modifications and increased production of energy, (Kong e*t al.,* 2013).

Current research is directed at outlining the role of micro element as abiotic stress tolerance enhancers in discovery of functions of novel genes, (Yin *et al.,* 2015), postulated a possibility of gene mediated mechanisms being in play in enhancing salinity tolerance of sorghum in silicon amended media.

Secretion of anti-stress compounds

Sorghum exhibits an elaborated root system this has been credited against soil water deficit through distant water sourcing, however, this doesn't imply that the crop has high dependence to distant water sources, suppression of weeds my also function in enhancing less completion to water resources. The root exudates of sorghum have been shown to reduce the growth of weeds such as velvet leaf, thorn apple, redroot pigweed, crabgrass, yellow foxtail and barn yard grass, (Stapleton *et al.,* 2010). Sorghum is also recommended for control of nut sedge infestations, (Clark, 2000). Sorgoleone excreted by sorghum roots suppresses the growth of many other weedy plant species, (Dayan *et al.,* 2010).

High temperature tolerance in sorghum

The tolerance of sorghum to high temperature depends on; the duration of exposure of sorghum to high temperature, the activity or stage of growth of the exposed tissue and the thermal adaptation of the particular sorghum cultivar. The cutin, consisting of the uppermost structure of leaves, is made up of mononers, without double bond systems, making them poor aborbers of ultra violet radiations, this is same to the dull stems, (Hamissou and Weibel, 2004).

Norcio, (1976) found a positive correlation between high photosynthesis rates at high temperatures and cellular heat tolerance of sorghums determined by the "electro conductivity" method (Sullivan, 1972). When heat stress is involved, an ability to maintain relatively high rates of photosynthesis may very well contribute to yield. A series of experiments were conducted, at ICRISAT, in the laboratory, glasshouse and field studying the emergence of a number of sorghum genotypes over a range of high temperatures. The work demonstrated that some lines had ability to emerge even when soil surface temperatures were as high as 55°C , (Craufurd & Peacock, 1993, Kumar *et al.,* 2008). In a study using 6 sorghum cultivars grown in 14 different environments, it was found that tolerance to high temperatures contributed more to yield stability. Specifically, where high temperatures occurred during panicle development, the capacity of a genotype to produce greater seed numbers per head (and hence greater yield) was important. However, the ability of genotypes to heat tolerance varies, (Craufurd & Peacock, 1993; *Sing et al.,* 2016).

Prospective advances in utilizing sorghum as a model crop for a biotic stress tolerance

Varied drought stress tolerance traits conferred by sorghum may be useful to other cereals including maize and wheat, (Geleta & Labuschagne, 2003). The immense sorghum germplasm, is yet to be fully exploited in understanding of abiot stress management and very few accessions have been utilized in new varieties development. The huge pool of over 37,000 described sorghum accessions will provide a good source of abiotic stress tolerance mechanisms, (Mullet at al., 2002; Csrl, 2013), since many of the genes responsible are yet to be mapped the venture will involve gathering of the materials and subsequent screening for the traits, (Dalal *et al.,* 2012).While testing the potential use of genes from sorghum to other crops, Mullet *et al.,* 2003 reported success in transferring Cryogenic glycosides coding genes into Arabidopsis, enabling resistance to the insects in the family *Chrysomelidae.*

It is advantages that sorghum genome is small 730 Mb, and has already been fully sequenced, (Peterson *et al.,* 2008). The wide germplasm resource, lower level of gene duplication unique to sorghum makes this cereal ideal especially for grasses and plant genomics research as a whole, (Dillon, 2007; Dalal *et al.,* 2012).

Increased utilization and use of sorghum genetic materials in research will spearhead identification of novel genes, which may be of benefit in abiotic stress tolerance, this would be done screening for gene functions for the varied sorghum tolerance mechanisms. In addition such efforts will enable prevention of the increased biodiversity loss, (Geleta & Labuschagne, 2003; Peterson *et al.,* 2008).).

CONCLUSION

Sorghum is a cereal crop exhibiting adaptation to varied conditions of low rainfall, low soil nutrients, high temperatures and grows well to maturity in such conditions. The experimentation and documentation of unique process and adaptation behaviors will pave way for quick gene screening, and experimentation involving gene tweaking, gene transfer, within sorghum and to other crops. The fact that sorghum has a smaller genome, it will be easier to extensively study the genes responsible for this stress management. Introgression of these superior salinity and water stress tolerance mechanisms to maize wheat, rice and other important cereals promises a potential for better food production.

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2.3 Exploration of marine microalgae as potential for biofuel production

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ABSTRACT

Fossil fuels are heavily straining the environment through green house effect resulting to Global warming which has led to continual depletion of the ozone layer. In addition environmental pollution due to fuel derived from fossil fuels has been on the rise. As a result biofuel derived from microalgae have been advocated in the recent years. Microalgae are considered advantageous for biofuel production because they do not compete with agricultural crops for arable land. Algal lipids have also been suggested due to their accumulation inside the cell at the end of the growth stage. The aim of this study was to identify microalgae that can be cultivated *in vitro* for environmental friendly biofuel. Sampling of microalgae was done at the Indian Ocean at the Kenyan coast. The objectives of the study included; to identify marine microalgae species that occur naturally, to investigate the effect of media on microalgae growth and to identify microalgae for large scale production of biofuel. The results indicated that *Oscillatoria* sp. exhibited 100% growth in three culture media namely; F/2 Guillard, Walne and Tris Acetate Phosphate (TAP) medium. Shannon weiner diversity indices indicated that *Oscillatoria* species was found to be present in large numbers in all the sampled stations. Lipid screening was done by Nile red staining. Further, lipid extraction by Bligh and Dyer method indicated that *Oscillatoria sp*.was able to produce 16% of lipid which could be converted to biofuel. The study therefore recommends this species for large scale cultivation for biofuel production because of its fast steady growth, ease to cultivate, media tolerance. Further, the amount of lipid content from it is moderate and can be bioprospected

Key words; *Oscillatoria sp*., F/2, Walne, Biofuel, in *vitro*

INTRODUCTION

Biofuel production from renewable sources is widely considered a sustainable energy alternative source compared to petroleum. Microalgae provide a viable means of environmental and economic sustainability [1]. Microalgae . Currently hold promise as an ideal third generation biofuel feedstock. This is supported by their rapid growth rate, carbon dioxide fixation ability and high lipid production capacity. They also do not compete with food crops for arable land and water resources for irrigation. They can potentially be produced on non arable land [1]Some microalgae strains are capable of generating 70% weight by weight (w/w) lipids in their biomass [2]However; they may yield significant lipid content under stress conditions. Some of the stress causing factors include; nutrients, light, salinity among others. Utilization of microalgae for biofuel production is meritorious over higher plants since they synthesize and accumulate large quantities of neutral lipids; they are also capable of all year round production yielding higher oil quantities[3].In addition, microalgae need less water than higher crops, hence reducing the load on freshwater sources [4]

Microalgae are reported to exhibit faster growth rates besides expressing the ability to grow under saline conditions that are unsuitable for agriculture [2].Adoption of biodiesel will support environmental conservation, agricultural and economic developmental goals. However, a successful and economically viable algal based oil industry depends on the selection of appropriate algal strain. Species of microalgae should therefore be bioprospected to determine suitability for oil production [5]. In the last decade, Deoxyribonucleic Acid (DNA) sequencing and genomics have brought substantial changes to microalgae taxonomy [6]. Both the subunit ribosomal DNA and its genes have been used in studies for species identification because they include the highly conserved regions at the species level.

MATERIALS AND METHODS

Sampling of microalgal strains

Water samples were collected in triplicates at the sampling stations for analysis. Surface water samples was collected using a bucket and 40 litres of water passed through 20µm mesh-size plankton net for concentration to 50ml. The resultant concentrated plankton was transferred to sample bottles labeled with date, sampling station and preserved in 5% Lugol's solution Qualitative samples were stored after collection in a cooler box and transported to the laboratory for for further analysis.

Water quality parameter

Surface water quality parameters were measured *in situ* at each station; pH was measured using an electronic pH probe, temperature was measured using an YSI Model 550A, salinity was measured using a hand-held refractometer.

Quantitative sample analysis
In the Laboratory, 1ml aliquots of samples preserved in Lugol's iodine solution were mounted on slides and observed under an inverted microscope and the counts of all seen phytoplankton recorded. The algal species were identified using an identification manual of marine microalgae by Hasle and Syvertsen (1977).

Isolation and purification
The algal samples for qualitative analysis were subjected to purification by serial dilution, addition of antibiotics, and addition of enrichment media followed by culturing them in TAP, F/2 (Appendix iii) and Walne (Appendix iv) media for microalgae and incubated at 25 ± 1°C under 1.2+0.2 k lux intensity with 16:8 hours light photoperiod. The purity of the culture was ensured by repeated sub culturing in fresh media and regular observation under the inverted microscope.

Identification of microalgal strains
The purified monoalgal samples were observed under the inverted microscope and the morphological properties of the isolates identified based on the manuals.

Culture maintenance
Unialgal cultures of the microalgae strains were maintained in the F/2 and Walne culture media. A drop of the respective culture was inoculated aseptically using a sterile micropipette into 50 ml of the medium in sterile 50 ml conical flasks. The cultures were incubated in an algal growth room with constant illumination at 110 µmol.m-2/s at 25 °C. This procedure was performed on weekly basis

Measurement of Growth Rate
The growth rate of algae was measured by optical density at 660nm, 680nm, 760nm and780nm for 4weeks Daily measurements were also taken daily for 7 days.

Identification of lipid producing microalgae strains
Nile red staining was conducted to detect intracellular lipid droplets. Microalgae cells (0.5 ml) were collected by centrifugation at 1,500 rpm for 10 minutes and washed with physiological saline solution (0.5 ml) several times. Thereafter, the collected cells were then resuspended in the same solution (0.5 ml). Nile red solution (0.1 mg/ml in acetone) was added to cell suspensions (1:100 v/v) and incubated for 10mins. After washing once, stained microalgae cells were observed by Fluorescent microscopy. Microscopic photographs will be taken with a Nikon E600microscope

Determination of oil content microalgae
One ml of growing algae in F/2 media was collected in 3 replicates in 1.5ml tubes and centrifuged at 13000rpm for 5 minutes. The pellets were frozen in liquid nitrogen and stored at -80^{0}C.Thereafter; the pellets were measured to determine the weight. The

lipids were extracted as follows; in the frozen pellets, 200µl of a mixture of chloroform: isopropanol (1:1) was added and vortexed vigorously for 3 minutes. They were then centrifuged at 13,000rpm for 5minutes .The supernatant was transferred to a new tube, and then the pellets were re-extracted with 500µl of hexane and; vortexed vigorously for 3 minutes. The samples will then be centrifuged and the supernatants combined. The supernatants were dried by an evaporator and the amount of lipids measured gravimetrically .The Bligh and Dyer method of Extraction using Chloroform and Methanol was also used [7].

RESULTS

Description of study site

Sampling was done three times at the Tudor creek. .Tudor creek is located Latitude of 4.0000°, Longitude. 39.6500°. It is 15.5km away from Mombasa town. The study site was accessed by a fibre glass boat at the Tudor Water sports entrance. Sampling was done in triplicates; one set was preserved with 5% lugol's iodine for quantitative diversity studies. The other set was other set was sorted, isolated and cultured, while another set was incubated at 28^0C for fourteen days Temperature, pH, total suspended solids and salinity measurements for all the sampled stations were recorded.

Physico-chemical Characteristics

The mean surface Water Temperature was 27.75^0C with a standard deviation of 0.5 and standard error of 0.25. The highest average temperature for the Creek studied was 310while the lowest average temperature was 21^0C (Table i). Analysis of variance reveals that there was no statistically significant variation in Water and Temperature between sampling stations and between the three months of sampling at (P>0.05) for the pH was observed during the study period, with the highest average value of 8 and a lowest of 7.8. The mean ± SD for pH is 7.25 ± 0.23 (Table i). This observed variation was statiscally significant .The surface Water Temperature ranged from 27^0C to 28^0.The highest temperature was recorded at Coast general station and Technical University while the lowest temperature was recorded at Mkomani station. The pH was observed during the study period, with the highest average value of 8.0and a lowest of 7.8The salinity ranged from 34-36.3 PSU. With the highest concentration at Mkomani station. Total Suspended solids ranged from 0.037-0.162g/l with the highest concentration being recorded at Fort Jesus.

Table 1: Physico-chemical parameters of the sampled stations

Parameter	TSS	Salinity	Temp	Ph
Units	g/l	Psu	^{o}C	-
Mean	0.07	35	27.75	7.85
Standard Error	0.03	0.48	0.25	0.05
Median	0.05	34.85	28	7.8
Standard Deviation	0.06	0.96	0.5	0.1
Variance	0.003	0.92	0.25	0.01
Range	0.125	2.3	1	0.2
Maximum	0.162	36.3	28	8
Minimum	0.037	34	27	7.8

Quantitative sample analysis

This was determined by observing the samples preserved by lugol's iodine under the Leica Inverted microscope.

Species present

The species were identified morphologically using conventional means by use of the phytoplankton guides. The species observed are shown in table 4. The species present in all the seven stations were**;** Oscillatoria spp., Thallasiosira sp., Coscinodiscus sp., and Nitzschia**.** The species present in only one station were; Monidiscus sp,Coscinodiscus sp, ,protoperidinium sp ,Dictyliosolenia sp, ,Bleaklayer sp.,Protocentrum sp.,Hemidiscus sp , Anabaena sp. , *Dactyliosolen fragilissimus*, *Cylindrotheca closterium*, *Gonyaulax spinifera*, Spatulodinium sp. , *Nitsia longissima*, *Anacustis nidulans*.

The most abundant phytoplanktons are in the group of Bacilliarophyta(diatoms) which occupied 60% followed by the Cynanophyta(cyanobacteria) which occupied 30%and chlorophyta occupying 10%.Bacillariophyta have been reported by many authors to be dorminat in the phytoplankton composition as it is in the present study [8]. Chlorophyta was the second group after Bacillariophyta in the number of identified species, these result also agree with study on Grand River in Oklahoma by [9]. It is also in agreement with other studies in Iraq [10]. The maximum occurrence of phytoplankton was in (October 2014) and then decreased. This may be due to available nutrients and other physical and chemical factors which promote growth of phytoplankton. While the minimum total number of phytoplankton species was recorded at moroto which might be due to domestic discharge, effluents from run-off that empty into the river, this corresponds to the work of [11] .The differences in number of taxa and number of individuals between sampling stations for each class of phytoplankton may be due differences in temperatures and pH as different species obtain at different pH and temperatures[12]have suggested a relationship between species diversity and pollution status of aquatic system and classified as follows; > 3 = Clean water, 1-3 = moderately-polluted < 1 = Heavily polluted. Water pollution levels can also be accurately identified by analyzing the species abundance, physiological, biological responses and residue contents [13]. However, algae may not only be significant for biomonitoring studies but could also be a useful phytoremediation technology to restore water quality due to their high bioaccumulation ability

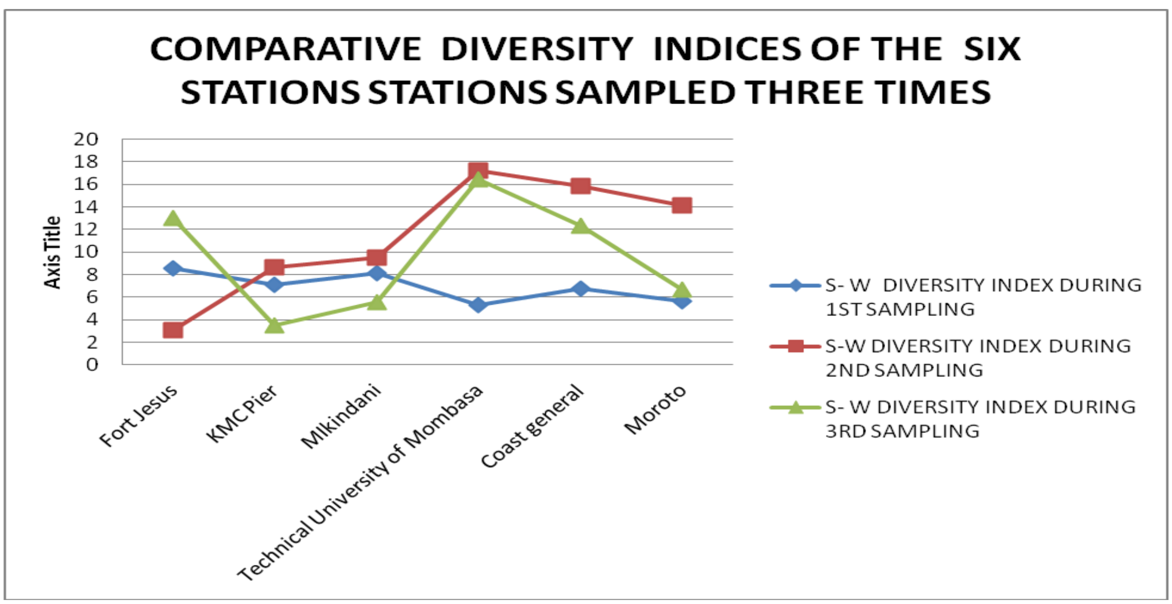
1.3.2 Shannon Wiener Diversity indices

Computation of diversity indices was also done. Resultant graphs were drawn as shown in figure 1

Phytoplankton Abundance and Diversity

Diversity indices reveal that TUM station had the highest index of 16.47.For all the diversity was stable. This indicated that there is a large abundance of phytoplankton in the marine ecosystem sampled.

Fig 1: Comparative diversity indices of the sampled stations



The highest diversity occurred during the second sampling which indicates very high diversity indices from the graphs shown.

Isolation and purification of microalgal cultures

This was done through isolation of the microalgae and culturing them on solid and the three liquid media namely; TAP, Walne and F/2

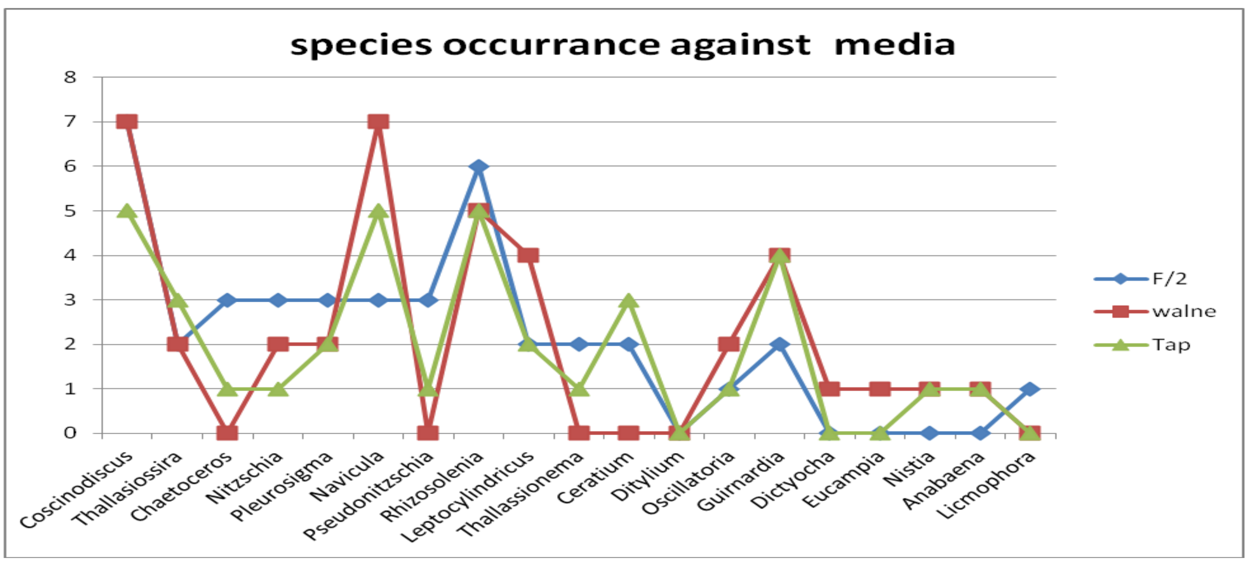
Liquid Media preferences

Species occurrence was highly dependent on the media, the media used were TAP,Walne and F/2.Plots of media and the species obtained are shown in figure ii

Culture of microalgae in liquid media

The isolated microalgae were then cultured in test tubes and conical flasks of 250 ml with the suitable media being supplied to each of them. Continuous and vigorous aeration was provided to culture which keeps the culture in suspension. In addition continuous aeration is also helpful for uniform distribution of nutrients.

Figure ii:Line graph showing a graph of media against media



From the graph it shows that F/2 and Walne Media are the most prefered media for growth of most microalga

Total Isolates obtained

At the end of the isolation process, there were various species obtained. Isolation was done based on stations, and species.

Liquid Media preferences

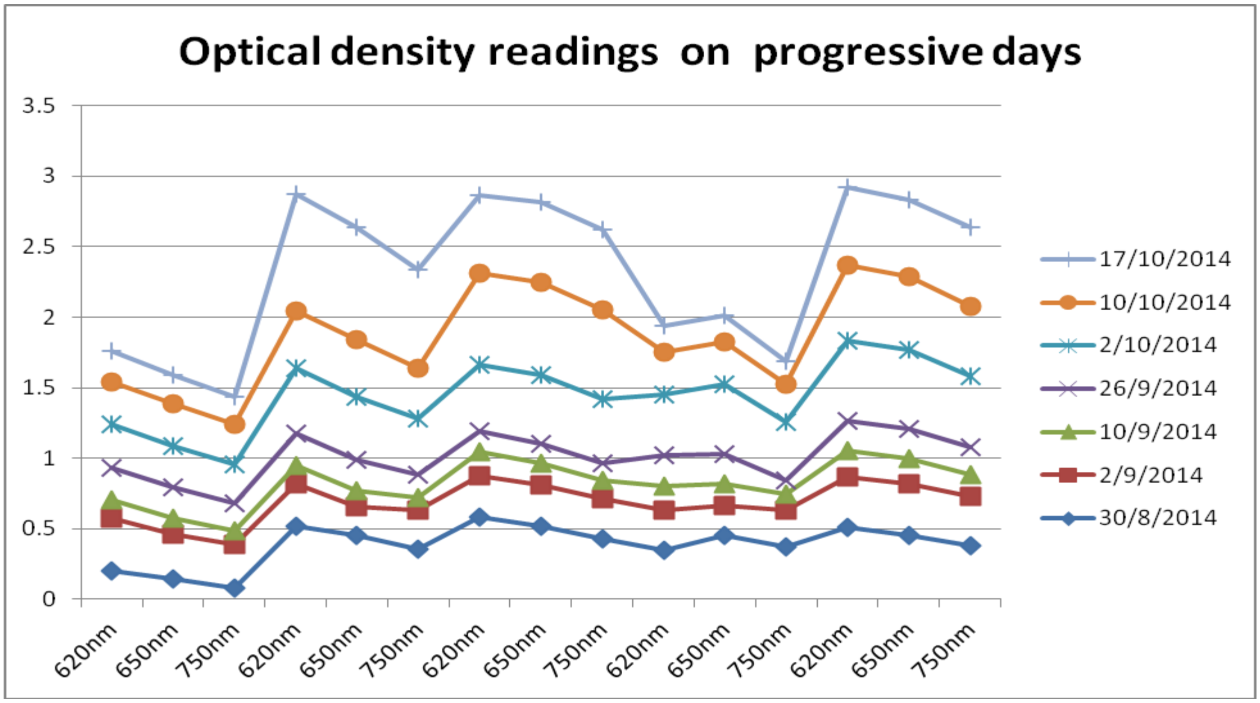
Species occurrence was highly dependent on the media, the media used were TAP,Walne and F/2.Plots of media and the species obtained are shown in figure i

The methods used for isolation included; serial dilution, culturing in liquid and solid media. The isolation protocol developed in-house resulted to be an efficient method for the microalgae isolation and transfer from the natural environment in to laboratory conditions. The streak plate method for microalgae enrichment, although slow, proved to be an excellent approach for the isolation of green phototrophic microorganisms. With regards to the physical properties of the water samples, they remained fairly constant all throughout the different depths assessed as well as in the different locations.
Temperatures fluctuated between 20.5 and 23.5^{0}C, pH between 6.9 and 8.1, and salinity between 32 and 37.8 psu.Regardless of the stations the microalgae colour appearance on the solid media included; 15% green, 16% brown, 8% pink, 23%cream.This results corresponds with the study from [12].Isolation procedures using solid media allowed for the selection of microorganisms with colors besides green; culture attempts of the same in liquid media were utterly unsuccessful. None of the solid or liquid media were prepared with an external carbon source, with the purpose of selecting phototrophic organisms. However, solid media was gellied with agar, which is a polymer of the sugar galactose.

However, certain marine organisms have the capacity of producing agarose and liquefy solid media efficiently [13].These enzymes are responsible for allowing them to use agar as their primary carbon source and enables their ability to thrive in the ocean .In this case, it might have happened that the organisms isolated, other than the green ones, had this innate ability to metabolize agar and thus developed efficiently in solid media; interestingly, all of them showed growth close to the agar surface.

As for the liquid Media preference, F/2 Media with silicate seemed to be the most preferred because there was a large growth of the species.TAP media was the least preferred probably due to the fact that it forms a cloudy appearance after a short while. These results are consistent with observations made by [9] and many others who noticed the zonation of pigments on marine organisms depending on depth.

1.5.5 Measurement of growth
Optical density was taken at intervals of one week. The absorbance readings were taken at three optical densities namely; Optical densities of; 620nm, 650nm and 750 nm. The results are shown in figure 2.
Figure 2 :Graph showing Optical densities on progressive days



Total lipid content of selected isolates using conventional extraction methods.

The results revealed that *Oscllatoria spp.*had the highest percentage of total lipid of 16± 0.5 these results were in harmony with the results of [14] who stated that oscillatoria has total lipid content 16.5%. Two diatoms species were investigated in this study *Nitzschia linearis* and *Navicula cuspidata*. The two species showed relatively low percentage of oil 6.1% and 10.2% for *Nitzschia linearis* and *Navicula cuspidata* respectively. *Nitzschia sp*. was investigated by [4] and found to have lipid percentage of 45-47%. On the other hand [15] found that *Nitzschia frustulum* has a total lipid percentage of 13.9%. This percentage near to that presented in this study in table ii

Table 2:Percentages of total oil content in the microalgae studied

Microalgae isolate	**Total lipid content %**
Oscillatoria sp 1	11± 0.4
Oscillatoria sp.2	16±0.5
Nitzschia lineaus	6 ± 0.1
Navicula cuspulata	10± 0.2

Intracellular lipid droplets of were observed by Nile Red staining under fluorescent microscope with excitation at 450–490-nm and emission at 515-nm [16].Neutral lipid or triglycerides appeared as yellow dots, whereas polar lipid and chlorophyll were stained in red colour cells were observed by Nile Red staining under fluorescent microscope with excitation at 450–490-nm and emission at 515-nm.Nile red staining: Nile red (9-(Diethylamino) -5H benzo [α] phenoxazin- 5-one) staining is specifically used to identify and confirm the intracellular lipid droplets from the biological samples [17].

The results indicated that not all algal species could be affected by Nile red staining since oil droplets were not clear and the whole cells were stained in red. This was the situation with green isolates, while certain blue green isolates were affected by the dye *where* the yellow stained parts were clear. Referring to *Oscillatoria sp 1* and *Oscillatoria sp 2* the cells showed yellow florescent color under florescent microscope even without adding the dye. So this gives false results when referring to lipid content. Diatoms were stained well Diatoms were stained well with the dye and the oil drops were clear. Since the staining method may not be accurate The florescent method has been successfully applied to the determination of lipids in certain microalgae, but has been unsuccessful in many others, particularly those with thick, rigid cell walls that prevent the penetration of the dye [18].Since Nile red method was not accurate in determining lipid content in microalgal cells so lipid content was determined using conventional extraction method using two organic solvents.

DISCUSSIONS AND CONCLUSION

It was therefore observed that physic-chemical parameters have a major role to play in species occurrence.The method of lipid extraction, type of media and level of axenicity of the microalgal species determines the percentage of lipid extracted .The Oscillatoria species seems to be a hardy species and therefore still survives when subjected to stress it is therefore recommended for large scale cultivation in photobioreactors for biofuel production.Stress conditions such as nutrient stress results to production of more lipids from the microalgae.Nile red staining is not so accurate therefore should be supplemented by other methods of lipid determnination.The choice of algal strain,the method used for culture and the location of sampling highly determines the amount of lipid produced by microalgae.

The strains used for large-scale algal biofuel production need to be improved through selection and genetic approaches. Breakthroughs and innovations in areas such as increasing the capability of algae to use nutrients efficiently or engineering designs to reduce processing requirements have the potential to greatly improve the energy balance and enhance the overall sustainability of algal biofuels.

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3.Parallel Session 2 : Technology diffusion impact and sustainable Agribusiness value chains

3.1 Effect of audience simulation on the knowledge of dieback disease management among cocoa farmers in Ife East Local Government Area of Osun state, Nigeria

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ABSTRACT

Tonnes of annual cocoa production are lost to pest infestation. Several interventions have been employed to promote alternative pest management for sustainable pest management. This paper examines the potency of audience simulation experimentation on management of dieback diseases of cocoa in Ife East Local Government Area of Osun State, Southwestern, Nigeria. A multistage sampling procedure was used to select 120 cocoa farmers. Data was obtained on farmers' socioeconomic and enterprise characteristics as well as knowledge of dieback disease management before and after exposure to audience simulation. Results show that farmers averaged 60 years old, mostly male (65.0%) and with no formal education (51.7%). Most respondents (66.7%)) were favourably disposed to the use of audience simulation in pest management information dissemination. There was a general improvement in respondents' knowledge level of issues on traditional management of dieback. In addition, more farmers correctly answered questions on environmental friendly practices such as prevention through keeping cocoa seedling in the nursery (75.8%). It is concluded that communication intervention to promote environmental friendly pest and disease management practices could be one of the drivers of transition to alternative pest and disease management. Development agencies should establish community viewing and broadcast centers where extension clientele can be reached in groups.

Keywords: *Audience simulation, dieback diseases, Pest and disease management*

BACKGROUND AND PROBLEM STATEMENT

Pest and disease management has played its role in doubling food production in the last 40 years, but pathogens still claim 10–16% of the global harvest (Charkraborty and Newton, 2011). According to the Food and Agriculture Organization of the United Nations (2001), 20 to 40 percent of the world's potential crop production is already lost annually because of the effects of weeds, pests and diseases. Specifically, tonnes of potential annual cocoa production are lost to pest infestation.

In the view of Padi and Owusu (2001), cocoa is perhaps the most important export crop for countries in the forest zone of West Africa and is the main source of foreign exchange for some of them. The cocoa industry in West Africa is dominated by a large number of peasants who cultivate small farms of about 0.5 to 5.0 hectares and who lack the resources (including access to information) to expand or improve their farms. This and other factors combine to plague the industry with serious problems leading to dwindling production levels.

Since the conscious effort of agricultural research is to move productivity from a lower level to a higher level in order to increase the income of farmers and enhance agricultural development (Farinde and Ajayi, 2005), it is therefore important to constantly inform the farming populace about the importance of pest and diseases management. Just as information is vital in every other facet of life, agricultural information is a key component in improving small-scale agricultural production and linking increased production to remunerative markets (Yahya, 2009), thus leading to improved rural livelihoods, food security and national economies. According to (Munyua 2000) cited in Obidike (2011) the rural urban drift in recent decades in sub-Saharan Africa could be attributed to rural farmers' lack of access to information that would help them achieve maximum agricultural yield, hence they are frustrated. Obidike (2011) points out that the least expensive input for improved rural agricultural development is adequate access to knowledge and information in areas of new agricultural technologies, early warning systems (against drought, pests and diseases outbreak) and improved seedlings.

According to Phrampus, Metro and Williams (2009), human patient simulation; a subset of radio and animation has emerged as a powerful educational modality across the continuum of learners. Simulation is used to demonstrate physiologic principles, physical examination skills, along with bringing topics to life with regards to disease process or variants of physiology. Like other methods that work well with adult learners, it is typically used and most effective in very small groups. A simulation of a system is the operation of a model of the system. In its broadest sense, simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time (Anu, 1997).

Many radio agricultural programmes targeted at farmers are regularly and continuously aired to bring farmers up to beat on new innovation and technologies (Olajide and Amusat, 2012) to bridge information gap occasioned by traditional prints and library based information sources. These radio programme have been evaluated to generate feedback on effectiveness or otherwise of such (Yahaya and Badiru, 2002; Olajide 2011; Olajide and Amusat 2012). However, previous attempts of evaluation of radio broadcast were based on the assumption that farmers are regular listeners of these radio programmes. This has treated farmers as homogenous groups with no difference in needs and has left them with no option than to make do with whatever information they gather from around them; adequate or otherwise. Little wonder, the desirable impact for which information are disseminated are mostly not achieved.

In view of the position above and considering that much as information is an essential ingredient in agricultural development programmes, farmers seldom feel the impact of agricultural innovations either because they have no access to such vital information or because it is poorly disseminated occasioned by wrong choice of channels. For a significant level of intended change to be achieved, therefore, access to required information and ability to utilise such places a high premium on the channel used.

It is against the aforesaid that audience simulation experimentation with information on pests and diseases that affect cocoa as observed in the study area were of interest in this study. The study was premised on the following specific objectives:

Identify the socio-economic characteristics of cocoa farmers in the study area;

Examine the enterprise characteristics of cocoa farmers in the study area;

Ascertain cocoa farmers' attitudes to the concept of audience simulation for information on disease management dissemination; and

To determine changes in knowledge of dieback disease management of cocoa farmers before and after exposure to audience simulation.

METHODOLOGY

The study was undertaken in Ife East Local Government Area (LGA) of Osun state, souhwestern, Nigeria with an area of 9,251 square kilometer and a population size of 34,137,627 (NPC, 2006). The population for this study was cocoa farmers in the LGA. A multistage sampling procedure was used for selection of respondents. In the first stage, purposive sampling technique was used to select Ife-East LGA because cocoa farming is prominent in the LGA. In the second stage, one ward known for highest cocoa output in the LGA was chosen. In the third stage, three farming communities were selected randomly from the selected ward. In the fourth stage, from each community, 40 cocoa farmers were systematically sampled from every other household. From each selected households, one person who has been in cocoa production in the last ten years was interviewed resulting in 120 respondents from the three communities

The study used a quasi experimental research design. The study was undertaken in three phases with the first phase involving collection of baseline quantitative data on farmers' knowledge of cocoa dieback disease management. Thereafter, farmers were exposed to audience simulation through a tape recording of management practices of the cocoa dieback disease. This was carried out by developing messages on management practices of dieback disease of cocoa in form of audio and selected farmers were organized in groups to listen continuously to the recorded message for three weeks. In the third phase, post-exposure quantitative data on the dieback disease management was collected after three weeks of continuous exposure to messages from the same groups to determine any change in the knowledge of respondents in management of dieback disease of cocoa. This was to ascertain the impact of the intervention.

The dependent variable of this study was the change in knowledge of dieback diseases management among cocoa farmers. The change in knowledge was generated from difference between mean scores of the pre and post knowledge (measured with 20-item knowledge statements) scores of the farmers. Response options for the questions were Yes and No. An increase in knowledge was expressed with higher mean score of post intervention compared to pre-intervention mean score. Data obtained were analysed using both descriptive (frequencies, percentages and mean) and inferential (t-test) statistics at p=0.05.

RESULTS AND DISCUSSION

Respondents' socioeconomic and enterprise characteristics

The age distribution of the respondents ranged between 18 to 88 years with the mean age at 59.01±16. More than one-third (35.0%) of the respondents fell between the ages of 50-65 years, while only about 6.7% were less than 33 years of age; as shown on Table I. This shows that majority of the farmers are old and less energetic which explains the reason for hired labour by respondents. This is in line with Gul Unal (2008) that old age might pose a disadvantage in agriculture because most of the work is physically demanding and older folks might be too conservative to try new and more efficient technologies.

Data further reveals that while males were 65.0% of the respondents, females were 35.0%. This suggests that more males than females are involved in cocoa production in the study area. This supports the findings of Durodola (2014) who reported that there are more males than females in agriculture. This also agreed with the findings of Olujide and Adeogun (2006) in assessment of cocoa growers' farm management practices in Ondo state, Nigeria which confirms that cocoa farmers are mostly male.

. Information on respondents' educational level reveals that only 17.5% of respondents had up to secondary education. A higher percentage of the respondents (51.7%) had no formal education, while only 2.5% of respondents had tertiary education. This implies that majority of the respondents had no form of education. This corroborates the view of Kumar and Quisumbing (2010) that in sub-Saharan Africa many farmers have low level of education and that improving their education would probably increase agricultural productivity and reduce poverty. Table I further show that 45.9% of the respondents had been engaged in agricultural production for more than 23 years, while 29.2% of the respondents had been in farming for 23years or less. This supports the findings of Ugwuja *et al* (2011) who found that majority of farmers have more than 15 years of farming experience.

Furthermore, result shows that majority (66.7%) of the respondents had less than 5 hectares while less than 1.0% had up to 16 hectares of land for cocoa production. This is in agreement with Padi and Owusu (2001) who pointed out that majority of cocoa farms in West Africa are small holdings owned by a large number of peasant farmers. The result on farm outputs shows that 40.8% of the respondents recovered up to 10 bags of cocoa and 49.2% of the respondent made output of between 11 and 20 bags in the season preceding the year of this survey and only 9.2% produced 21 to 30 bags of cocoa. This implies that cocoa production is affected greatly by a number of challenges which include dieback disease especially if one considers size of farm holdings of these farmers.

Result on number of farm locations shows that 51.7% of the respondents had two farm locations and only 25.0% had more than three farm locations. Results on sources of farm labour show that 93.3 % of the respondents engaged hired labourers for farming while

6.7% use family members as their source of labour. This is possible because higher percentages of the respondents are old and perhaps are less active. Also, 95.0% of the respondents' source of finance was self while 1.7 % of respondents got financed by family and only 0.8% source finance from cooperatives.

Table 1: Distribution of cocoa farmers based on their socioeconomic and enterprise characteristics

Variable	Categories	Frequency	Percentage
Age (years)	18-33 years	1	6.7
	34-49 years	46	20.8
	50-65 years	40	35.8
	66-81years	22	31.7
	>81	13	5.0
Sex	Male	78	65
	Female	42	35
Education	No formal education	62	51.7
	Primary education	34	28.3
	Secondary education	21	17.5
	Tertiary education	3	2.5
Farming experience (Years)	2-23 years	35	29.2
	24-45 years	30	25.0
	46-67 years	38	31.7
	68-89 years	17	14.2
Farm size	Less than 5ha	80	66.7
	6-10ha	34	28.3
	11-15ha	5	4.2
	16-20ha	1	0.8
Number of farm location	1	25	20.8
	2	62	51.7
	3	3	2.5
	More than 3	30	25.0
Last season output	Less than 10bags	59	49.2
	11-20bags	49	40.8
	21-30 bags	11	9.2
	More than 30 bags	1	0.8

Source: Field survey, 2014

Attitude of respondents towards the concept of audience simulation

The favourable disposition of farmers to use of audience simulation approach is not in doubt as they responded positively to most of the issues raised in their attitudinal disposition to the broadcast method. For instance, while majority (75.8%) were affirmative on social desirability of audience simulation, 65.0% also agreed that messages from audience simulation may be more easily understood (Table II). The farmers could be coming from the background of what they stand to gain in listening to a broadcast that addresses their problem in groups. It might also be a forum to proffer solution to common problem that confronts them as well as another opportunity to create an alliance to combat the disease frontally in group. From the position of majority who opined that the message could be easily understood, it is given that debate and discussion will ensue soon after the broadcast is over. This will no doubt engender better understanding as individual farmer seeks clarifications (Adesina and Zinnah (1993). .

Furthermore, while a reasonable proportion (53.3%) were in doubt about whether the simulation broadcast methodology is for small scale farmers, 50.8% debunked the fact that it offers no room for feedback while more than two-third (69.2) equally disagreed that they will easily forget message received from audience simulation channel. The farmers' position of doubt of audience simulation being for them is understood considering neglect they experience on regular basis from several facets of their livelihood.

The latter optimism expressed in respect of feedback opportunity as well as retention of messages thereof, perhaps, was reinforced by the conviction of 59.2% of the respondents that audience simulation provides direct contact to object of dissemination, therefore makes it sound more like live broadcast. Again, while 59.0% believed that audience members' composition especially mixed audience will impact the use of audience simulation, 73.3% were not in any doubt that participation in audience simulation will help in better management of pest and diseases on their farms.

The positive rating of audience simulation by this set of respondents was reinforced by 76.6% who unequivocally asserted that audience simulation is a good communication approach and that its message could enhance their understanding of dieback disease. In all, it can be safely concluded that most cocoa farmers (66.7%) are favourably disposed to the use of audience simulation in disseminating diseases and general cocoa management information.

Table II: Distribution of respondents based on their attitude towards the concept of audience simulation n=120

	Statement	SA	A	U	D	SD
1	Audience simulation is socially desirable	75.8	7.5	15.8	0 .0	0.8
2	Message is easy to understand with audience simulation	65.0	20.0	15	0 .0	0 .0
3	Audience simulation is not for small scale farmers	1.7	14.2	53.3	15	15.8
4	Audience simulation does not give room for feedback	5.0	11.7	32.5	38.3	12.5
5	I easily forget messages from audio audience simulation	1(0.8)	3.3	26.7	26.7	42.5
6	Audience simulation provides direct contact to object of dissemination, therefore makes it sound more like live broadcast	25.0	34.2	39.2	1.7	0.0
7	Audience members' composition especially mixed audience will impact the use of audience simulation.	59.0	22.5	18.3	0.0	0.0
8	My participation in audio simulation will help in managing pest and diseases on my farm better	73.3	0.0	9.2	15.8	10
9	Audio audience simulation is not a good communication approach	2.5	2.5	18.3	8.3	68.3
10	Audience simulation further compounds problem of understanding messages.	1.7	0.0	15.0	11.7	71.7
	Overall attitudinal disposition	Favourable 66.7			Unfavourable 33.3	

Source: Field survey, 2014 **Figures are percentages**

Farmers' knowledge of dieback disease management practices

From available data in Table III, there was a general remarkable improvement in respondents' knowledge level in the post intervention period of simulation. Notable among items that recorded at least two-third improvement in the post intervention performance of the farmers were the realisation that dieback disease affects cocoa from seedling (94.2%), the effect is felt during dry season (75.0%), dieback kills cocoa stems (90.8%), internal discoloration of stems (91.7%) and prevention through keeping cocoa seedling in the nursery and free of moisture (90.%) as against 36.7%, 27.5%, 29.2%, 38.3% and 38.3% of respondents who got these correctly in the pre intervention period. However, two items recorded a drop in the performance of farmers in the post test period. Though insignificant, more respondents (63.3%) and (39.2%) respectively, correctly answered the questions on potency of dieback disease both at the nursery and field levels as well as prevention of dieback through proper spacing during the pre-simulation intervention compared to 62.5% and 37.5%, respectively, in the post intervention phase. The result on proper spacing leaves so much to be desired as proportion that got it right at both pre and post intervention era were abysmally low. This might be due to deep rooted belief in the traditional practices that the farmers are familiar with and had stuck to.

While the result above may leave one in doubt about the effect or impact of the simulation on respondents' knowledge of dieback disease, the picture painted by the set of data on Table IV reflects the significance of the simulation intervention. While less than a quarter of the respondents (22.5%) had high knowledge of the dieback disease in the pre-intervention phase, the proportion of respondents with high knowledge (52.5%) was more than double those that had high knowledge in the pre-intervention period. In concrete term, whereas, mean score was 10.8 in the pre-intervention phase, a mean score of 15.1 was recorded in the post-intervention stage.

Table III: Distribution of respondents by pre and post audience simulation knowledge of dieback disease management

Item	Before %	After %
The mortality rate of dieback on infected farm could be total.	76.7	95.8
Dieback does not affect cocoa tree at seedling stage of development.	36.7	94.2
The younger the seedling at the time of infection, the greater its chance of being killed.	71.7	83.3
Dieback can affect trees both in the nursery and on the field.	63.3	62.5
Dieback only affects older cocoa trees.	31.7	68.3
An infected tree starts by showing some little yellow spots on the leaf at the tip of the tree.	59.2	70.8
Dieback affects cocoa in all seasons.	56.7	77.5
The effect of dieback is not felt during dry season.	27.5	75.0
Colour changes of cocoa leaves from green to yellow are not dieback symptoms to look out for.	70.0	75.8
Spotted leaves are one of the critical symptoms of dieback.	54.2	92.5
Dieback cannot kill cocoa stem.	29.2	90.8
Dropped leaves signify advanced dieback infection.	90.8	92.5
Internal discoloration of stem occurs in trees affected by dieback?	38.3	91.7
Planting of disease free seedlings cannot prevent dieback.	48.3	85.0
Ensuring that prepared field for cocoa planting is disease free is a means to prevent dieback outbreak.	58.3	89.2
Keeping cocoa seedling in the nursery and free of moisture can help prevent dieback.	38.3	90.0
Mealy bug is a suspected vector of dieback.	52.5	90.0
Ants crawling up cocoa tree and building soil tunnels may play host to sources of diseases.	50.8	92.5
Adequate shading in the nursery is a measure to prevent dieback.	45.8	75.8
Adequate or proper spacing will not prevent dieback.	39.2	37.5

Source: Field survey, 2014

Table IV: Categorization of respondent's level of knowledge before and after the simulation (n=120)

Level of knowledge	**High**	**Low**	**Mea score**
Before	27 (22.5)	93 (77.5)	10.1
After	63 (52.5)	57 (47.5)	15.1
Change	66 (55.5)	54 (45.0)	

Test of difference between knowledge of dieback disease in the pre and post simulation intervention

The result of the inferential statistical analysis of test of difference between the pre and post intervention phases of the simulation (Table V) indicates that there was a significant difference between knowledge possessed by respondents in the two periods. This is in tandem with the findings of Olajide and Thomas (2011) and Olajide (2011) that establish a positive impact of radio entertainment – education program on sexual practices of selected farm families in Nigeria. It is also in agreement with the position of Gershon, Rinku and Jaime (2004) in their study of the acquisition and diffusion of knowledge in pest management in Indonesia.

Table V: Paired sampled t-test between the knowledge before stimulation and the knowledge after stimulation.

Hypothesis	Mean	SD	Df	t-value	p-value	Decision
Difference in knowledge before and after	14.50	4.36	119	-6.25	0.000	Significant difference

Level of Significance=0.05

CONCLUSION AND RECOMMENDATION

Evidences from results of this study suggest that cocoa farmers in the study areas are mostly male, old, vastly experienced in cocoa farming but with small holdings in scattered locations. They were mostly favourably disposed to the audience simulation broadcast method and benefited greatly as the audience simulation recording enhanced their knowledge of the dieback disease. It is recommended that all stakeholders, government agencies and non-governmental establishments that are reaching out to farmers should put the audience simulation to use. This can be achieved by establishing community viewing and broadcast centers where extension clientele can be reached in groups.

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3.2 Analysis of spillover effects of Integrated Pest Management strategy for suppression of Mango fruit flies in Meru County, Kenya

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ABSTRACT
Horticultural sub sector in Kenya experiences many challenges among them insect pests like the fruit flies. An integrated pest management (IPM) strategy for suppression of fruit flies among mango growing communities in Africa has recently been developed and disseminated by International Centre of Insect Physiology and Ecology (*Icipe*) and partners. While the economic benefits of the strategy in mango production has been established, the cross-commodity benefits have not been assessed, yet the target invasive fruit fly species *Bactrocera invadens* has a wide range of cultivated host plants. Using propensity score matching analytical technique, we analyze the spillover effect of

adoption of IPM strategy for fruit fly control on farm incomes; utilizing cross-sectional data collected using a household survey of 374 farmers in Meru County, Kenya. We focus on four alternative cultivated hosts- avocado, pawpaw, oranges and bananas -of this major quarantine pest that are predominantly grown in Meru, one of the counties in Kenya where the fly population has been observed to occur in large numbers. Our findings suggest that cross-commodity spillover effect in the use of the IPM strategy exerts a positive and significant impact on gross margins of pawpaw and oranges by Ksh. 28,154 and 11,114 with kernel based matching and Ksh 27,249 and 11,025 with radius matching per acre per year respectively. The results of this study suggest that there is a wide scope of IPM investment in Kenya, and thus up scaling this type of technology at large scale, throughout Africa would be expected to substantially increase household income and boost productivity of existing cultivated hosts of *B. invadens.*

Key words*;* mango fruit flies, cross-commodity spillover effects, propensity score matching, Kenya

INTRODUCTION

Horticultural sector plays a major role in the economy of many African countries. It is among the leading foreign exchange earners, and contributes to food security and employment, especially among smallholder farmers (Salami et al., 2010). In Africa for example, in 2007, fruit and vegetable exports generated over US$ 16 billion in foreign exchange from exported commodities employing over 40 million people directly and indirectly (Billah et al., 2015). Between 2001 and 2011, Kenya's horticultural sector's exports grew at an average annual rate of 16 percent. While in 2012, the total value of horticultural exports was Ksh 87 billion having exported 380,000MT of produce. This was a 4% decline in quantity exported as compared to 2011. The decline in quantity and value was due to the reduction in quantities of nuts and processed fruits exports (Kibira et al., 2015).

Despite the importance of the subsector to the economy, it experiences many challenges among them the reduction of both quality and quantity of marketable produce which is mainly attributed to attack by insect pests such as fruit flies (Ekesi & Billah, 2007). Detected in Kenya in 2003, *Bactrocera invadens (B.invadens)*, an invasive fruit fly species is one of the most destructive insect pests in horticultural production (Drew et al., 2005). *B.invadens* is ubiquitous, highly polyphagous attacking 40 host fruit and vegetable crops in 22 families in Africa among them mango, pawpaw, avocado, citrus, guava, and banana (Billah et al., 2015). Although the primary host of *B. invadens* is mangoes, the preferred hosts vary according to the region, climate, and host availability (Cugala et al., 2014). Past studies show up to 12–60% loss of mango and pawpaw attributed to *B. invadens* (Danjuma et al.,2014). Fruit fly infestation cause approximately US$ 1 billion annual economic losses from mangoes globally and more than US$ 42 million in Africa (Lam et al., 2012). In 2008, Kenya lost US$ 1.9 million due to *B. invadens* quarantine restriction for avocadoes imposed by South Africa (Ekesi, 2010).

In Africa, the International Centre of Insect Physiology and *Ecology* (ICIPE) have developed and disseminated an integrated pest management (IPM) strategy to help cope with *B. invadens* challenge in mango production. The ICIPE-IPM package consists of five components (see Muriithi et al., 2016). Past studies have shown that the use of IPM reduces mango damage caused by fruit flies by a bigger percentage compared to use of synthetic pesticides for instance lower fruit damage of less than 14% was recorded by mango farmers participating in the application of IPM components in Embu, Kenya (Kibira et al., 2015). Muriithi et al. (2016) also found that application of the IPM strategy resulted in a 48% average increase in mango net income while mango yield losses due to fruit fly infestation reduced by an average of 19% among the IPM users.

Although the economic benefits of the IPM strategy on the primary target crop – mango- are clearly demonstrated as highlighted above, the potential gains of the strategy on other cultivated hosts of the invasive fruit fly species within a farm have not been quantified in the previous studies. These past studies fail to capture the widespread diffusion of the technology to other host cultivated plants which may essentially under estimate the actual impact of IPM on farm income. This study seeks to fill this gap by analyzing the unintended (spillover) effects of the strategy using specific crops enterprises within the same farm as mango using one of the ICIPE-IPM action sites, Meru County in Kenya. The study adopt an impact evaluation approach by fitting a propensity score matching regression model to assess the spillover effect of IPM strategy for control of mango fruit fly on the farm income generated from avocados, pawpaw, orange and banana.

METHODOLOGY

Data

The data used in this study was collected through a household level survey in three sub-counties in Meru County where mango production is predominant; Meru Central, North Imenti and Tigania West. Three hundred and seventy four (374) of the 1200 households that were surveyed in 2013 by ICIPE were randomly selected and revisited in November and December 2014. The sample consisted of 210 IPM adopters and 164 non-IPM mango farmers from the control area, computed following (Bartlett et al., 2001). The survey was conducted using questionnaires administered by trained enumerators and supervised by one of the authors of this study. The data collected included information on input use, yields and output prices, farm-level and socioeconomic characteristics of the households.

Theoretical review

Adoption of IPM technology for suppression of mango fruit- fly

Farm level economic analysis of IPM technology investigates whether when the technology is disseminated, adopted and spills results in higher farm profits (Kibira et al., 2015). Farmers benefit from externalities derived from sustained IPM practice.

Adoption of IPM technology is assumed to be a dichotomous choice that is, the new technology is adopted when the net benefits from using that technology outweigh those of not adopting the IPM technology. This study assumes that the use of IPM technology is expected to affect the demand of other inputs such as pesticides and fertilizers as well as yields and income. Following Ariane & Guthiga (2012) linking adoption decisions with potential outcomes, this study considers a risk-neutral farmer who minimizes the total cost of production which comprises traditional/conventional costs (input costs), subject to conventional constraints. The farmer chooses IPM technology I to minimize the conventional costs. Algebraically this can be expressed as;

$$\text{Min } C\,(\mathbf{WX}) \tag{1}$$

Subject to a production function written as:

$$Y(\mathbf{X}) = Y\,(\mathbf{V, I\,(T), K, Z}) \tag{2}$$

where C is the total input cost, **W** is the vector of input prices, **X** is vector of all production inputs, Y is the output produced, consumed and sold (as a result of using IPM technology and other inputs), **V** is a vector of conventional variable inputs such as fertilizer used by the farmer, **I** is conventional pesticides whose use embodies the use of IPM technology **T, K** and **Z** are fixed and quasi-fixed capital inputs and institutional factors respectively.

The farmers' optimization problem is therefore to choose **I** that minimize the total cost of production subject to a given quantity of output Y_0 as shown below. When stated differently, the farmer will decide to adopt IPM technology for suppression of mango fruit fly if doing so minimizes the total cost of production subject to a target output level. To simplify this, when two inputs are used, the production function is assumed to take the following functional form;

$$Y = f\,[V\,I\,(T)] = Y_0 = [V\,I\,(T)]$$

$$\text{Min } C = W_1V + W_2\,1(T) \tag{3}$$

$$\text{Subject to: } f[V, I(T)] \geq Y_0 \tag{4}$$

a lagrangian function is written for this problem as shown;

$$\ell = W_1V + W_2I(T) + \lambda(Y_0 - f(V, I(T)) \tag{5}$$,

after which we obtain conditional factor demand for using IPM technology. The solution of the lagrangian function which is associated with the cost minimization problem yields, among others, **I*** which is conditional input demand equation (associated with IPM technology) as functions of output Y, input prices W, conventional variable inputs V, fixed factors K and institutional factors Z. This is expressed as;

$$I^* = I^*(W, Y, V, K, Z) \tag{6}$$

Equation (6) indicates that adoption of IPM technology for suppression of mango fruit-fly **I** which is affected by, among others, factors prices (incentives), the fixed and quasi-fixed capital (capacity) and institutional factors. Some of the capacity variables could be farm and farmer specific.

Estimation strategy for spillover effect of IPM technology for suppression of mango fruit- fly

Following Ariane & Guthiga (2012),we model the indirect impact (spillover) of the adoption of IPM technology by small-holder farmers on household income Y, as a linear function of explanatory variables (X_i), an adoption dummy variable (R_i) = 1 if the farmer adopts the technology and 0 otherwise, μ_i is the error term, β and A are coefficients. The linear regression model for assessing the indirect impact of IPM technology for suppression of mango fruit fly on farm income can be specified as;

$$Y = \beta X_i + AR_i + \mu_i \quad (7)$$

Whether farmers adopts the IPM technology or not is dependent on the farm and farmer characteristics, hence the decision by a farmer to adopt is based on each farmer's self-selection instead of random assignment. Assuming a risk-neutral farmer, the index function to estimate adoption is expressed as;

$$R_i^* = \gamma X_i + e_i \quad (8),$$

where R_i^* is a latent variable denoting the difference between utility from adopting the IPM technology U_{iA} and the utility from not adopting the technologyU_{iN}. The farmer will adopt the IPM technology if $R_i^* = U_{iA} - U_{iN} > 0$. The term γX_i provides an estimate of the difference in utility from adopting the technology ($U_{iA} - U_{iN}$), using the household and farm-level characteristics, as explanatory variables, while $e_i$is an error term. In estimating equations (7) and (8), it needs to be noted that the relationship between IPM technology and outcome (farm income) could be interdependent. Thus, technology can help increase output and as such richer households may be better disposed toward the adoption of new technologies. Thus, treatment assignment is not random, with the group of adopters being systematically different, resulting in selection bias problem.

To address the problem of self- selection we adopt a propensity score matching (PSM) technique, which involves finding a group of treated individuals similar to the control group in all pre-treatment observed characteristics, such that the only difference is that one group use IPM technology while the other does not (Hirano & Imbens, 2004). PSM starts by fitting a discreet choice model to estimate the propensity scores and in this case a logit model was used:

$$P(X) = \beta_0 + \beta_1 age + \beta_2 agesquared + \beta_3 sex + \beta_4 education + \beta_5 landsize + \beta_6 no.\,of\ mango\ trees\ owned + \beta_7 wealth\ category + \beta_7 agricultural\ extension\ services + \beta_8 distance\ to\ tarmac\ road + \beta_9 access\ to\ irrigation\ water + \beta_{10}\ group\ membership + \beta_{11} training + \mu_i \quad (9)$$

In PSM the variable of interest is the average treatment of the treated (ATT). The spillover effects of IPM are as a result of impact on host crops when farmers adopt the IPM strategy on mangoes. Therefore, the set up for estimating the spillover effects was not different from estimation of direct impact of the IPM technology.

$$ATT_i = E(Y_i|T = 1) = E(Y_{1i}(1)|T = 1) - E(Y_{0i}(0)|T = 1) \quad (10)$$

ATT_i is also called conditional mean impact. Y_{1i} is the gross margins for pawpaws, avocado, oranges and bananas of the i -ith farmer who participated in the program while Y_{0i} is the gross margins of the i -ith farmer who had not participated in the program.

RESULTS AND DISCUSSION

Descriptive statistics

Three households were dropped from the selected sample due to missing data and apparent enumerator errors, leaving a sample of 371 households that is utilized in this article for analysis. The mean age of the household heads for the IPM users was 55 years while for the control was 56 years. Age of the household head was expected to have negative influence on technology, that is, the more the years a farmer had the less the likelihood of applying a technology This was not the case because 208 farmers (56%) who had applied IPM had a mean age of 55.3. This would be because only 8.4% of the interviewed household heads were youths. It would also be because the older farmers were the land owners and made all the decisions to be carried out in the farm. The average farming experience was 28 years for both IPM users and non-users. The mean cultivatable land size was 5.1.acres for the IPM users and 3.9 acres for the IPM non-users

Empirical results

Table 1 presents results of the logit model employed to predict the probability of applying IPM strategy. The dependent variable is a binary IPM adoption. Prior to running the model, a test is conducted to detect the problem of multicollinearity between the variables included in the analysis (Molefe & Hosmane, 2007). The mean VIF was 1.36; all the variables in the model had a VIF far less than 10 which satisfy the rule of thumb. Further, link test was done to show whether the model in this study is properly specified and the _hat was found to be statistically significant with a p-value of 0.0000. On the other hand the _hatsq was insignificant at p (0.811) which was in line with other authors (ibid).

The logit results are only discussed briefly as our main objective is to evaluate the indirect impact of IPM technology on farm income. To calculate asset index, we followed the recommendation made by Filmer & Pritchett, (2001) to use principle components analysis (PCA) to aggregate several binary asset ownership variables into a single dimension. PCA is relatively easy to compute and understand, and provides more accurate weights than simple summation.

Farmers with bigger land sizes are more likely to apply the IPM strategy. Our results in table 1 also indicate that the probability of the decision to apply IPM strategy increased with distance from the tarmac road. A possible explanation stated by different authors is that households closer to market towns which are characterized by presence of tarmac roads tend to engage more heavily in non-farm activities such as small businesses compared to households that are further away from market centers and whose livelihood opportunities are limited to farm enterprises (Muriithi & Matz, 2014).

Asset index was used in this study to categorize the households according to wealth status with respect to the amount of assets a household has or its wealth. It has a positive influence on the adoption of IPM strategy meaning that the more assets a household has the higher the chances of adoption of IPM strategy. Finally, farmers who attended trainings on mango production were more likely to apply IPM strategy since they were more knowledgeable on the advantages to damage control measures.
Table 2 presents the estimates of ATT by the Radius matching (RM) and Kernel based matching (KBM) methods. The matching results in table 2 indicate that application of IPM has positive and significant effect on gross margins of pawpaw and oranges. Applying the IPM strategy increased the average gross margins of pawpaws and oranges by a range of KSh. 28,154 - 11,114 and KSh. 27,249 - 11,025 per year per acre respectively. The negative causal effect for avocado and bananas implying the users of IPM suppression strategy had lower gross margins per acre in the two crops than the non- users. In their study on seasonality and host utilization of the invasive fruit fly, *B. invadens* in central Tanzania, Mwatawala et al. (2006) observed that avocado contained 0.8 flies per kilogram compared to other fruits like oranges and mangoes which were 2.9 and 149.3 fruit flies respectively. Several authors have also noted that infestation of bananas by *B.invadens* is limited in the "all yellow fruit stage" and not mature green bananas (Cugala et al.,2014).

From the last column in table 2, the level of gamma (critical level of hidden bias) is defined as the odds ratio of differential treatment assignment due to an unobserved covariate. The sensitivity analysis for the indirect effect of mango fruit fly IPM control technology on gross margin of oranges for example suggest that at the level of **γ =** 3.05 the causal inference of the significant effect would have to be viewed critically. For a gamma level of 2.35 it implies that if individuals who have the same characteristics differs in their odds ratio of participation by a factor of 135 percent then the significance of the estimated participation effect on gross margins would be questionable. Therefore in conclusion the gamma results shows that even slightly bigger amount of unobserved heterogeneity would not alter the inference about the estimated indirect effects of IPM strategy but it would be imperative if the study is done after several years of application of IPM to ascertain the inference.

Tables

Table 1: Propensity score estimates: (logit estimates)

Explanatory variables	Coefficient	Std Error	P-value
Gender of the household head	0.41	0.64	0.521
Age of the household head (years)	-0.098	0.15	0.517
Age of the household head squared	0.0007	0.001	0.577
Number of years household head completed in school	-0.027	0.55	0.621
Log of agricultural cultivatable land in acres	0.83	0.315	0.008**
Access to irrigation water(dummy)	1.10	0.49	0.027**

Distance to the nearest tarmac (km)	0.52	0.07	0.000***
Distance to the extension provider (km)	-0.03	0.04	0.379
Asset index (proxy for wealth category)	0.05	0.02	0.009**
Training(dummy)	1.89	0.52	0.000***
Constant	-5.46	4.05	0.178
Number of observations	371		
Pseudo R2 =0.7261			

Notes: *** Significance at 1% level, ** significance at 5% level, *significance at 10%
Source: Field survey data

Table 2: Average treatment effect results

Crop enterprise	Matching algorithm	Average gross margin based on matched observations: IPM users	IPM non-users	ATT	t-values	Critical level
Avocado	KBM	12659	25219	-12560	-3.58***	3.40-3.45
	RM	12659	25506	-12847	-3.68***	3.40-3.45
Orange	KBM	21154	10040	11114	3.07***	3.05-3.10
	RM	21154	10129	11025	2.83***	3.05-3.10
Pawpaw	KBM	64272	36118	28154	2.61***	2.35-2.40
	RM	64272	37023	27249	2.54***	2.35-2.40
Bananas	KBM	18357	39473	-21,116	-4.64***	2.00-2.05
	RM	18357	39985	-21,268	-4.77***	2.00-2.05

Notes: *** Significance at 1% level, ** significance at 5% level, *significance at 10%
KBM with band width 0.03 and common support: RM with 0.03 caliper and common support
Source: Author's computation

CONCLUSIONS

We have analyzed the spillover effects of IPM strategy adoption on farm income of smallholder farmers in Meru County, Kenya. A non-parametric econometric technique is used to mitigate selection bias stemming from observed heterogeneity and to test robustness of results. This involves the application of propensity score matching technique to measure the effects of adoption of the IPM strategy for suppression of mango fruit fly on gross margins of avocado, oranges, pawpaws and bananas commonly grown in Meru County and which are also hosts of B. *invadens*.

Results indicate that applying IPM strategy has generated a positive and significant effect on gross margins of pawpaws and oranges at the household level. Applying the IPM strategy increased the average gross margins of pawpaws and oranges by a range of KSh. 28,154 - 11,114 and KSh. 27,249 - 11,025 per year per acre respectively. The study therefore concludes that IPM strategy for suppression of mango fruit fly increases the farmers' farm income by reducing crop damage to other host crops.

The findings are important for policies that focus on introduction of new technologies targeting small-scale farmers to enable them increase their farm incomes and consequently reduce poverty. Further research using panel data would help in addressing the effects of unobserved heterogeneity, which was not possible to account in the PSM approach.

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3.3 Challenges facing strawberry farming in central Kenya

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ABSTRACT
Fruits are important for food and nutrition security. Among fruits, strawberries have high nutritive value and enhance human wellbeing through provision of large quantities of essential nutrients and antioxidants. The berry contains phytochemicals

such as anthocyanins and ellegitannins which produce the anti-cancer agent, ellagic acid, in addition to having alkalizing and anti-diuretic properties that prevent kidney diseases. The fruit is rich in vitamin C, iron, calcium, phosphorus, magnesium and manganese. Increasing demand for the fruit has increased cultivation and consumption in rural and peri- urban regions, especially in Nairobi, Nyeri and Kiambu Counties. Despite increased interest by growers in peri-urban areas, production is still low due to a number of challenges facing farmers. A field survey was carried out in Nyeri, Nairobi and Kiambu Counties to ascertain these challenges and provide insights to possible solutions. Among the respondents, insufficiency of high quality planting material was most significant (90%), while lack of production knowledge and skills (30%), diseases (19%), insect pests (17%), birds (17%) and poor market chain (17%) were major. Other significant challenges included insufficient postharvest storage and handling systems (<10%). These findings show that provision of quality planting materials, educating farmers on strawberry production and increasing availability of effective crop protection measures are critical to increasing production. Further research is needed to evaluate inputs use (fertilizer regimes, pesticides and water) and their impact on productivity of strawberry in Kenya.
Key words: Challenges, Improvement, increased, Production, Strawberry

INTRODUCTION

In Kenya, Strawberry farming is described as a highly profitable emerging venture for small scale horticultural farmers (Maina, 2010). However adoption of this crop by Kenyan vegetables and fruit farmers in has been slow. The crop requires intensive management including good land preparation, well timed agronomic management practices, proper plant nutrition and excellent harvest and post-harvest handling, (Mwangi and Mwaura, 2009).

Strawberry has been consumed by man from as early as 2000 BC as a wild fruit (Vaughan D. 1987). This wild or Wooden strawberry (*Fragaria vesca*) was first described by Vilmorin-Andrieux (1885; 2011), attributing it to perfume like aroma and delicacy of flavor with about 2,500 seeds to the gramme. He differentiated Wooden strawberry from Alpine Strawberry, describing Alpine ones as larger with fewer seeds (1500), and of continuous flowering in summer. Ottoman Strawberry is another unique type of strawberry which has been in production since 1900.

Strawberries are fruits from the family Rosaceae, which comprises of: peaches, nectarines, apples, pears, quinces, apricots, plums, cherries, raspberries, loquats, blackberry, apricots and almonds (Harris and Mitcham, 2007). These fruits are widely accepted for their distinctive high quality aroma, juicy texture, and sweetness. Strawberries are characteristically bright red in color, although some new varieties have been bred to yellow and white amongst other colors. The fruits are consumed as fresh and in processed solid food and drinks, milkshakes, and chocolates, (Maina, 2010). The fruit is highly sought for by food processing industries, juice, yogurt, jams, cakes and sauce making. Products constituting of fresh strawberries such as cakes are most of the time for the high end market, fetching high prices (Rahman, 2015).

A number of strawberry varieties are categorized into June-bearing varieties: Chandler, Honeyoye, Allstar, Eclair; ever bearing varieties: Quinault, Ozark Beauty and Fort Laramie; and day neutral varieties: Tristar, Selva and Veestar. June bearing varieties yield a big harvest in one month while everbearing varieties strawberries bear twice per year while, day neutral varieties flower and fruit continuously. The country's most common varieties are: Pajero, Chandler, Tri-Star, Tioga, Domanil, Douglas, Selva, Rabunda and Tribute (Waithaka and Ngugi, 1985). According to Maina, (2010) some varieties have been extensively spread in Kenyan horticultural crops production areas covering, Limuru, Nyeri, Kirinyaga, Kajiado, Molo, Kinangop, Nakuru, Eldoret, Kericho, Meru, Embu, Mt. Elgon, Kitale and Bugoma. Current varieties under production include: Chandler, Rotunda, Douglas, Pajaro and Aiko, (Waithaka and Ngugi, 1985; Mwangi and Mwaura, 2009).

During production and post-harvest handling, Strawberries are susceptible to attacks by several insect pests and diseases leading to huge crop losses. The pests include insects, birds and snails. Weed control in strawberry field is sometimes difficult due to the plant architecture which constitutes of shallow root systems that makes uprooting of weeds near roots difficult. This necessitates the need for chemical herbicides which are deleterious to the environment. Plastic mulch and natural mulch, like rice straw and grasses are potential (cheap) means of weed control and soil conservation (Mwangi and Mwaura, 2009).

METHODOLOGY

A field survey was conducted in selected counties in Kenya covering; peri-urban areas in Nairobi, Kiambu and Nyeri Counties in February, 2016 using a stratified sampling procedure. The area was first stratified in terms of geographical distance to cover the approximate ecological range of strawberries growing in these counties. Counties and sub counties' agricultural officers were used as key informants for accurate identification of strawberry farmers.

Data was collected through personal interviews with individual farmers and labourers involved in management of strawberry orchards using structured and semi-structured questionnaires. Characteristics of strawberry production under small holdings was recorded which included: details of years in strawberry production, farm sizes, sources of planting materials and production level per week of the farmers interviewed. Information on challenges in production ranging from inputs to other agronomic and market related issues were gathered. The data collected was subjected to descriptive analysis, mainly to obtain frequencies and valid percentages of occurrences of testable variables using the SPSS data analysis software version 20.1.

3.0. RESULTS

3.1. Production area and time

The study confirmed a higher concentration of smallholdings strawberry farming in Nyeri County The villages with highest percentage of respondent farmers growing strawberry were Kwa wambui, Karia, and Iganjo at 20% each, while, Sagana and Kiamariga, Mutaaga, Karandi and scheme, each had 10% of the strawberry farmers interviewed, (figure 1).

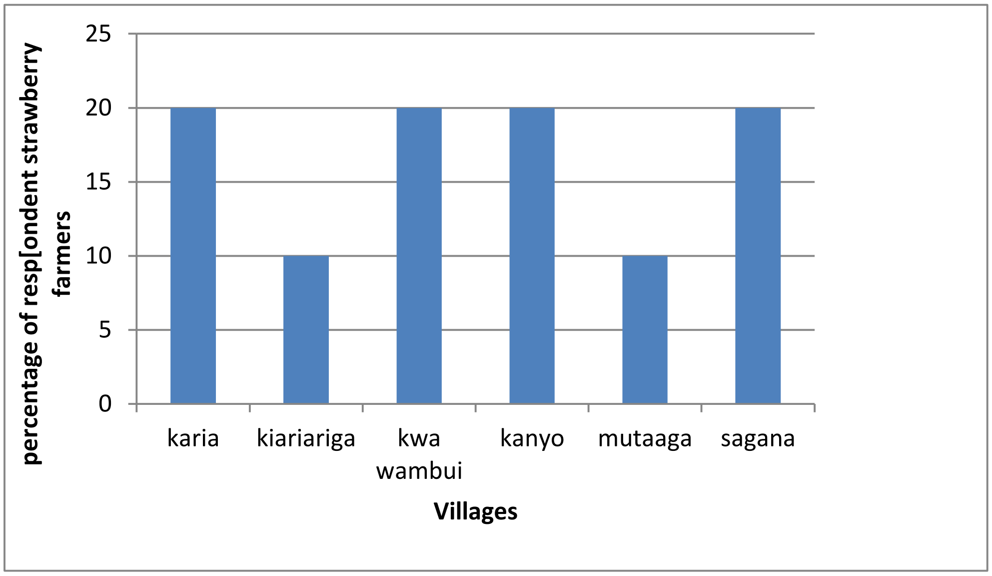

Figure 1: Strawberry most intensive production villages under smallholdings in Nyeri County

A significant proportion of farmers had small portions of land allocated to strawberry production, despite having experience of strawberry farming for over three years. All the farmers interviewed were small scale farmers, cultivating from less than $^1/_8$ to ¾ acres, (figure 2).

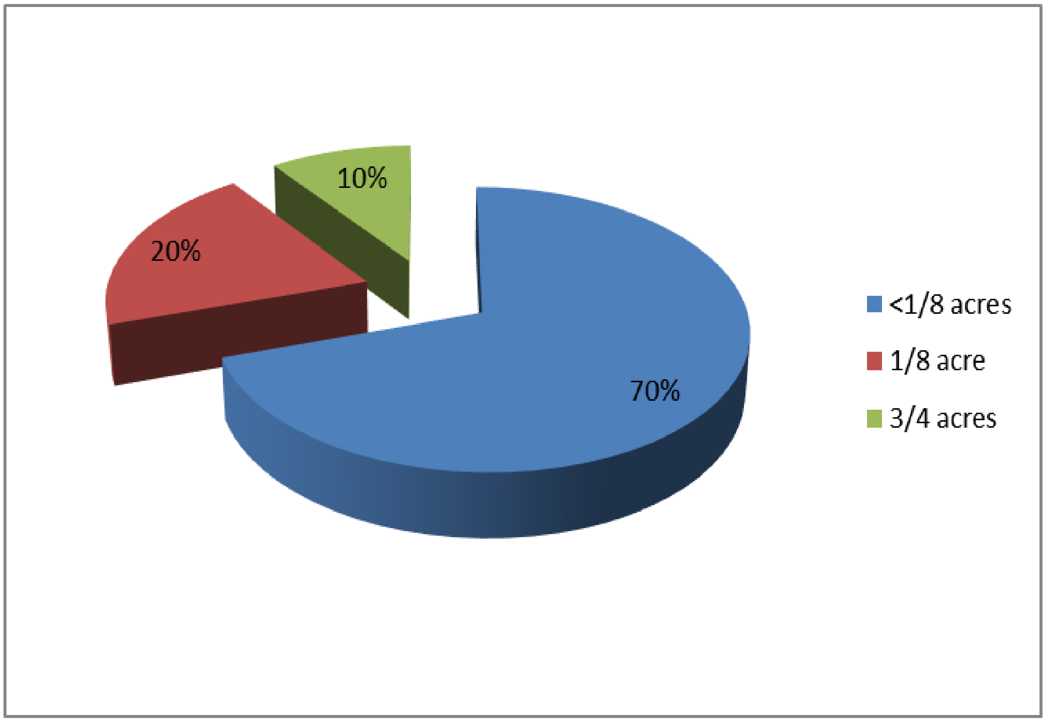

Figure 2: Average farm sizes of strawberry production

Majority (50%) of these famers had been growing strawberries for about 5 years while 20% of the farmers had been in strawberry enterprise for over 6 years. The remaining (30%) had been growing the berries for one to four years, (figure 3).

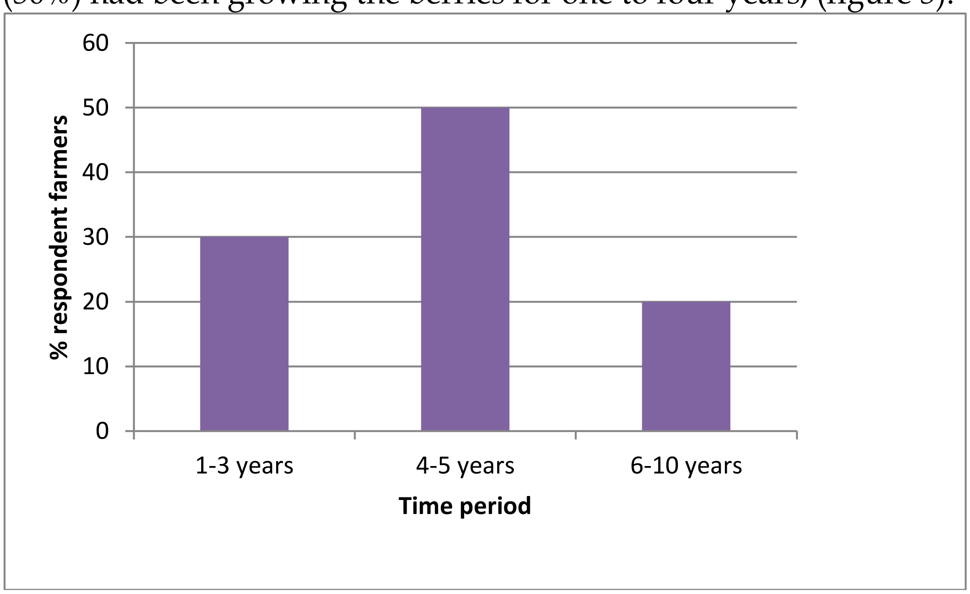

Figure 3: Resilience in strawberry production by smallholder farmers in Nyeri County

Source of planting materials

The predominant strawberry variety grown was Chandler and Pajero. The common form of propagation was splits (vegetative materials) which were obtained from runners with majority of the farmers (70%) acquiring them from their neighbours, (figure 4).

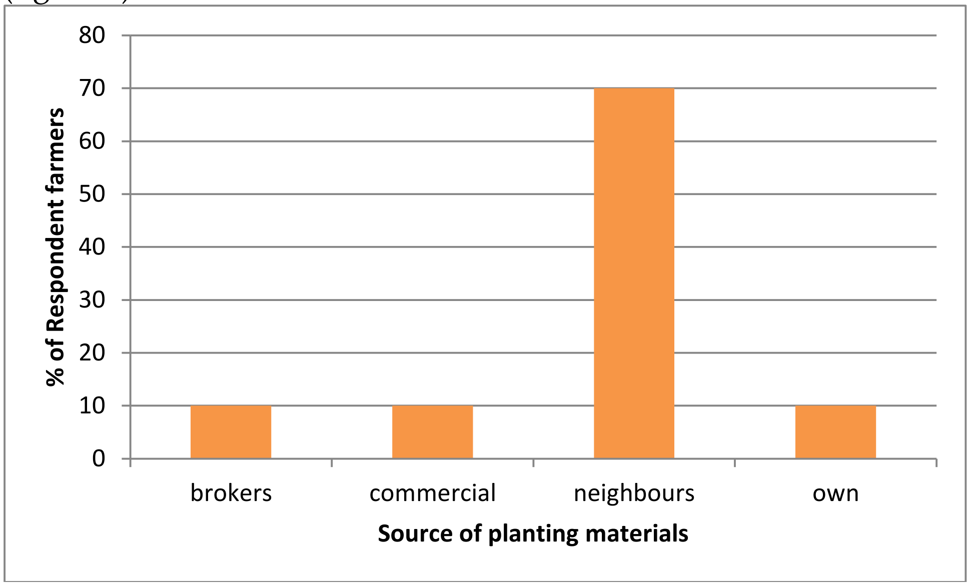

Figure 4: Sources of strawberry plantings materials among smallholder farmers in selected counties in Kenya

Strawberry yields

The average yields obtained by farmers were low, the yield per week during the peak harvest season were said to range from, 36kg (50% of farmers), 16kg (30% farmers) with some few farmers (20%) recording as low as 6kg per week as their highest yields, (figure 5)

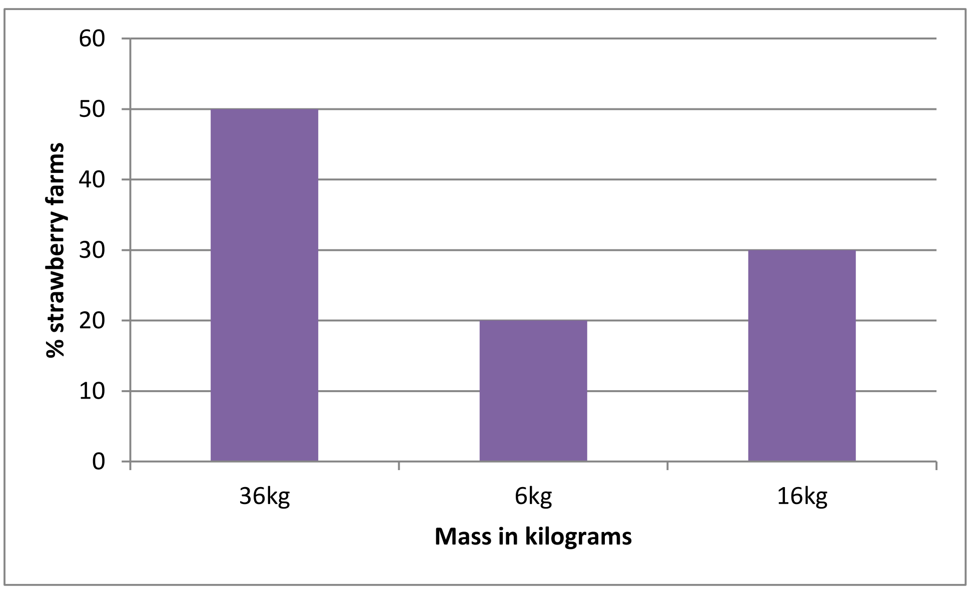

Figure 5: Strawberry production in Nyeri

Pests, diseases and other production challenges

At the field insect damage was reported (17%), birds (17%), and fungal diseases (19%). Insufficient production knowledge, poor soil fertility, insufficiency of cold storage facilities and excess rainfall constituted 30% of the challenges faced by farmers. Challenges in handling fruits and timely access to good markets was difficult resulting to poor marketing prices (17%), (figure 6)

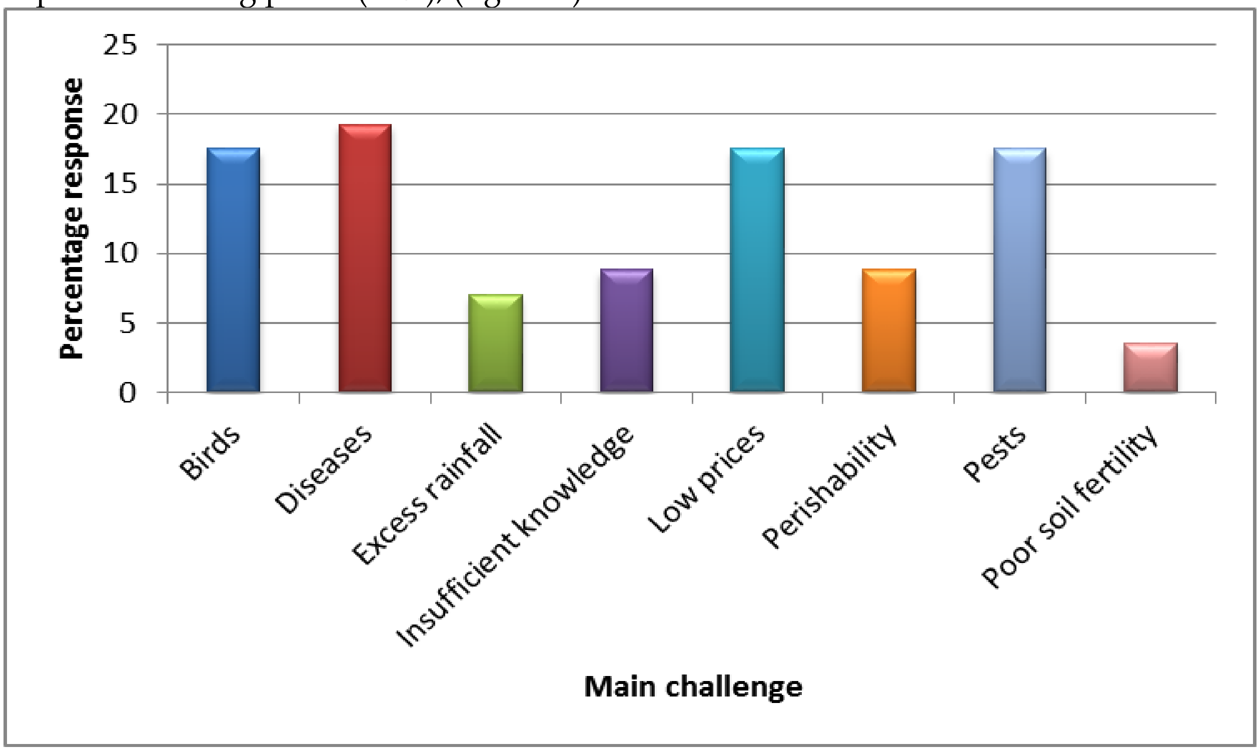

Figure 6: Other challenges in strawberry production

Open field cultivation was practiced using unskilled labour. Farm input was a mixture of both of inorganic and organic compounds. Inorganic fertilizers in use included: a compound fertilizer Nitrogen Phosphorus and Potassium (NPK 17:17:17) and calcium ammonium nitrate. The bio stimulants in use included: D.I. Grow® and OMEX® (foliar macro and micro –supplements). Bestock® was used in control of insect pests while Oshothane® and Ridomil® were the main fungicides for control of fungal pathogens
Brokers were the main target market at farm gate. Generally it was noted that with marketing, there were quite a number of challenges, due to the high perishability of the fruit and insufficiency of cold storage facilities. These factors contributed to low pricing of the fruit.

DISCUSSION

The area under study (Central Kenya) is characterized by well drained, loam soil which is preferable for strawberry production (Taneyhill, L, 2010; Rowley and Drost, 2010).

Allocation of small land sizes (1/8 acres) to strawberry production, could be attributed to the rapid land subdivision in Kenyan peri-urban areas

The difference in the number of farmers growing strawberry in the villages under study could have been as a result of variation in uptake of strawberries among the villages. This may also be contributed to by the variation in farmer perception on the production, and fear of inability to handle challenges accompanied. Use of unskilled labour in production as observed in the study area is well explained by both the small scale of production and uneconomically high cost of production inputs known to affect smaller enterprises. Most of Kenyan strawberry produced in large scale is for export market. The study has identified that majority of the smallholder farmers growing these fruits lack the required production knowledge hence depend on their neighbours for information on production and other aspects of strawberry management.

In 2012, Kenya produced 239 tons of strawberry, compared to 1,366,850 produced by USA in the same year (FAOSTAT, 2012). Of the 239 tons produced in Kenya, 90% is likely to be exclusively from commercial export farms. The smallholders with farm sizes of $^{1}/_{8}$ to ¾ acres, contribute to low yields which never get formal market access. The yield volume and cost of production was greatly influenced by the size of land under cultivation as can be confirmed by similar studies by Woods and Thornsbury, (2005). Unavailability of formal seed/seedlings system to smallholder strawberries farmers is a barrier to production of a number of varieties by farmers apart from Chandler and Pajero which are obtained from neighbours. This limited choice of variety may not be a choice but rather the only choice of planting strawberry to smallholders without their access to export companies controlled strawberry nurseries, (Lantz, *et al.,* 2016). Majority of farmers sourced their material from neighbours and as such picking on the available variety which was probably Chandler. In their earlier survey, Mwangi and Sarah, (2009) had mentioned poor seedling production systems for strawberry, this was found to be still the case 7 years later, as exhibited by the high number of farmers obtaining their seed material from neighbors

The variation in the amount of produce could have been due to factors such as differences in agronomic practices among the respondents, size of land under strawberry production or even the experience of the respondent farmers in production. Size of land as well as difference in agronomic practice has also been attributed as a cause in variation of yield by Woods and Thornsbury (2005)

Challenges gathered in this survey such as, poor soil fertility (fertilizer requirements), and pests in strawberry production pests are similar to findings by Paparozzi, (2013). The choice of the preferred chemicals could have been due to their readily availability in the local market, their perceived efficiency against the respective pests and, or their lower cost compared to similar products from other manufacturers.

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3.4 Evaluating health and environmental effects of mango integrated fruit fly management technologies in Meru County, Kenya.

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Abstract

Integrated pest management (IPM) has been promoted as an effective alternative means of controlling pests and diseases in agricultural production since it is environmentally friendly and economically feasible. Ideally, the adoption of IPM technologies allows farmers to reduce pesticide use and their harmful effects to health and the environment. This research work investigated the health and environmental effects of IPM technologies introduced recently by the International Centre for Insect Physiology and Ecology (*icipe)* and partners among Mango farmers in Meru County, Kenya. Environmental Impact Quotient (EIQ) was used to compare the effects of IPM technologies on health and environment with other common fruit fly control methods. The dummy variable for IPM use was included in order to analyze the effect of the adoption of IPM technologies on EIQ using Endogenous Switching Regression (ESR). The results showed that over 20 pesticides were used during mango production to control fruit flies; however, only 9 of over 20 pesticides were commonly used by majority of the mango farmers. Significant factors determining the magnitude of EIQ were farming experience, access to credit, labour management, use of protective clothing and number of production trees. The empirical results show that the use of IPM technologies reduces EIQ field use by 6.81 %, and this is statistically significant. This implies that IPM technologies have positive benefits on health and environment.

*Key words***:** Integrated pest management, environmental impact quotient, endogenous switching regression, Kenya

INTRODUCTION

Mango is the third most important fruit crop in Kenya after bananas and pineapples respectively in terms of production and area under coverage (Kibira *et al*., 2015). In Kenya, mango production in 2013 was under 46,980 ha which produced 581,290 tonnes (HCDA, 2013) accumulating Kenyan shillings 7.4 billion in totality. Mangoes processing earns foreign exchange through exportation, making a potential source of employment. Inclusive is farmer's wellbeing both financially and nutritionally. However, Mango production suffers various challenges, among them two main pests (fruit flies, mango seed weevil) and two main diseases (powdery mildew and anthracnose) (Griesbach, 2003).

To counter decreased quality and quantity of mango products, farmers have resulted to using pesticides as a remedy. Sometimes limited effectiveness of synthetic pesticides and farmers level of knowledge prompt misuse of pesticides (Fan *et al*., 2015). Very few studies have been conducted to assess the sustainability of pesticides use in developing countries despite the increasing concern about their impacts on health and environment as is documented (Chitra *et al*, 2013; Edwards, 2013; London, 2013). Among the effects include environmental degradation, loss of biodiversity and irreparable changes to the eco-system (Relyea, 2005; Gill *et al*., 2014). High pesticide residue levels in fruits products restrict entry to international markets due to tight trade regulations as they pose health hazards. This has led to seizure and devastation of consignments and possibly outright bans on for the exporting countries.

IPM is a chemical-free protection strategy that is less harmful to environmental components and human health as it offers safe and cost-friendly protection of crops against pests and diseases. IPM decreases the net pesticide used in fruit fly control hence environmental and health benefits. (Colette *et al*., 2001) reports that IPM reduces production cost by more than $173 Million and environmental costs by $99 million per year in USA. Kibira *et al*., (2015) and Muriithi *et al*., (2016) evaluated the impact of the IPM strategy on pesticide expenditure, mango fruit yield loss and profit in Embu and Meru Counties respectively. There's possible gains underestimation as human and environmental effects have not been quantified despite the studied positive economic impacts. This study, addresses the health and environmental effects of the IPM strategy among mango producers in Meru County, in Kenya.

METHODOLOGY

2.1. Study area and sampling technique

This study was conducted in Meru County, Kenya where ICIPE has disseminated the strategy. A multi-stage sampling procedure had been applied in selecting three sub-counties, two were provided with IPM materials (Meru central and Imenti North), while a third wasn't (Tigania West). 371 of the 1200 mango producers surveyed earlier by ICIPE were randomly selected and revisited in the October 2014. Probability Proportional to Size (PPS) sampling technique was used to select 206 adopters and 165 non-adopter farmers.

METHODS AND DATA ANALYSIS

Environmental Impact Quotient

Descriptive statistics were used together with the EIQ and endogenous switching regression models to analyze the data in STATA version 12. To assess the relative difference adopters and non-adopters, the main descriptive analyses used were two-group mean comparison t-test and the two-sample test. EIQ model was used to determine the magnitude of health and environmental effects. It combines the pesticide hazard posed to farm workers (applicators and pickers), consumers (farm products and ground water) and the local environment (aquatic and terrestrial) into one numerical value (Pradel *et al*.,2008; Macharia, 2009). EIQ model estimates pesticides risks on a three point scale of 1, 3, and 5 in accordance to the hazard of various pesticides; 1= lowest, 5=highest, (Kovach *et al*, 1992). The EIQ Formula is as stated below.

$$EIQ = \{C[(DT*5)+(DT*P)]+[C*((S+P)/2)*SY)+(L)]+[(F*R)+ (D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]\}/3 \quad (1)$$

Where:
C = chronic toxicity; DT = dermal toxicity P = plant surface residue half-life S = soil residues half-life SY= systemicity; L=leaching potential; F=fish toxicity R = surface loss D = bird toxicity Z = bee toxicity B = beneficial arthropods activity
For comparison of pest control strategies, we computed EIQ field use by finding the product of EIQ, pesticide dose, percentage active ingredient and the frequency of pesticide application as shown in the formulae below.

$$EIQ\ field\ \ use\ rating = EIQ*\%active\ ingredient\ *\ frequency\ of\ \ application\ ..... \quad (2)$$

Endogenous Switching Regression.
According to Lokshin *et al* (2004) ,the probability of a farmer adopting IPM technologies is given by the expected benefits I_s^* against the expected effects of not adopting IPM practices, I_t^*. I_s^* and I_t^* are latent variables hence observed is the actual adoption of IPM technologies, I, I=1 if $I_t^* \triangleright I_s^*$ and I=0 if $I_t^* \leq I_s^*$. Adoption of IPM can be denoted as:

$$I = Z\alpha - \mu \quad (3)$$

Where; I = Dummy variable for adoption, Z= independent variables, α= vector of parameters and μ=error term. The general probit model of adopting IPM technologies is therefore specified as:

$$IPM = \beta_{0j} + \beta_{1j}(gender) + \ln\beta_{2j}(educ) + \ln\beta_{3j}(\exp) + \ln\beta_{4j}(age) + \ln\beta_{5j}(hhsize) + \ln\beta_{6j}(fsize) + \ln\beta_{7j}(mtrees) + \ln\beta_{8j} + \beta_{9j}(exten) + \beta_{10j}(pcloth) + \beta_{11j}(grpmem) + \ldots\ldots \beta_{12j}(credit) + \ln\beta_{13j}(labmngt) + \beta_{14j}(irrwat) + \mu \quad (4)$$

Where; *IPM*= adoption status of the farmer. This variable takes a value of 1 if the farmer has adopted IPM practices and 0 otherwise. Full Information Maximum Likelihood (FIML) is an efficient method to estimate ESR because it calculates the probit equation and the outcome equation simultaneously to yield consistent standard errors (Alene *et al.,* 2007). The general representation of the outcome equation is as shown:

$$EIQ = \beta_{0j} + \beta_{1j}(gender) + \ln\beta_{2j}(educ) + \ln\beta_{3j}(\exp) + \ln\beta_{4j}(age) + \ln\beta_{5j}(hhsize) + \ln\beta_{6j}(fsize) + \ln\beta_{7j}(mtrees) + \ln\beta_{8j} + \beta_{9j}(exten) + \beta_{10j}(pcloth) + \beta_{11j}(grpmem) + \beta_{12j}(credit) + \ln\beta_{13j}(labmngt) + \beta_{14j}(irrwat) + \mu \quad (5)$$

Where; *EIQ*= the environmental field use representing impact of IPM technologies on health and environment. To successfully achieve this we need to estimate the conditional expectation of effects that participants would have without adoption of IPM technologies (Lokshin *et al* 2004). For a farmer with characteristics X and Z who adopt IPM technologies, the expected effects can be defined as:

$$E(y_s / I = 1) = X\beta_S - \sigma_{SV}\lambda_S \tag{6}$$

Where;

$(\sigma_{SV}\lambda_S)$ denotes sample selectivity, i.e. that a farmer who adopts IPM may be different from an average farmer with characteristics X and Z due to unobserved factors. For the same IPM adopter, the anticipated health/environmental effects would be,

$$E(y_t / I = 1) = X\beta_t - \sigma_{tv}\lambda_S \tag{7}$$

The change in health and environmental effects due to adoption of IPM is calculated as:

$$E(y_s / I = 1) - E(y_t / I = 1) = X(\beta_s - \beta_t) + (\sigma_{tv} - \sigma_{sv})\lambda_s \tag{8}$$

This is the average treatment effect on the treated (ATT) which compares the magnitude of health and environmental effects for adopters with and without IPM technologies while average treatment on the untreated (ATU) compares the same effects for the non-adopters. This treatment effect on the treated is due to the differences in the coefficients in Equations. (7) and (8).

RESULTS AND DISCUSSION

Farmers perception on impacts of pesticides on health and environment

Both IPM participants and non-participants ranked the risks associated with pesticide use to health and environmental indicators (table i). Both reported that pesticides use poses risk on their health and environment. On health and environment, IPM participants reported larger risk as compared to non-participants who reported large risk on pesticides.

3.2. EIQ for commonly used pesticides to control mango fruit flies in Meru County

A total of 65 pesticides comprising of 41 active ingredients were used in mango production. Bayleton and Bulldock were the most used pesticides in mango production representing 34.50% and 33.96% of the total pesticide used respectively (table v). The two recorded 15.43% and 24.47% of the total pesticide usage by the non-participants and 22.78% and 22.42% among participants respectively. The average EIQ values for farm workers, consumers and environmental component of IPM non-participants were 24, 10 and 75, respectively while the mean components of IPM participants were 25, 10, and 73, respectively. Basing on EIQ Classification rule (Macharia, 2009), values for all the mango pesticides used in mango production showed that 30%, 25% and 45% of those pesticides were rated as low (EIQ = 0 to 20), medium (EIQ = 21 to 40) and high (EIQ ≥ 41), respectively. Results showed that the environmental component of the EIQ was high for both participants and non-participants, a significant difference was observable between the two groups. The total EIQ field use in Meru County was 4049.67, 84% was obtained from the non-participants. The total field-use EIQ rating per individual pesticide ranged from 0.58 to 946.16, being lowest for Deltamethrin (0.58) and highest for Dimethoate (946.16).

ECONOMETRIC RESULTS

Determinants of adoption of IPM technologies

The first stage of the endogenous switching regression model was a probit model that evaluated factors that influenced adoption of IPM technologies (table ii). The variables in the table represent factors determining adoption of IPM technologies. Adoption is high in large scale production as it implies higher revenue generation from mango production. Irrigation water access was significant at 5% with a coefficient of 0.326 as it boosts production. Farmer group members unexpectedly, are less likely to adopt IPM technologies despite access to information. Farmers with larger farm sizes are likely to adopt IPM technologies as they could be used as collateral to access credit. With large farm sizes, production economies of scale are achieved hence higher income generation. This makes it affordable to procure technologies. Household heads age is negatively related to adoption of IPM.

Determinants of health and environmental effects.

The estimation results show a structural difference between the two groups because most of the variables that influenced health and environmental effects in the two regions were distinct (table iii). From the results, if the labor management ratio reduces by 1% the value of EIQ field use will reduce by 2.1 % implying a positive impact on the environment. Also, an increase in the number of mango trees by 1% will reduce environmental impact by 73% in the participant's region. Household head age was also significant by increasing the negative health and environmental effects of pesticide use. For non-participants, household size and number of productive trees were significant in determining the magnitude of EIQ field use. However positive health and environmental impact of number of mango trees was higher for IPM participants.

Health and environmental effects of IPM Adoption

The predicted health and environmental effects were compared for the sub-sample with and without IPM; other factors held constant (Table iv). The ATU was computed, which indicated the difference between the mean health and environmental effects if they had adopted IPM technologies or not. IPM non-adopters would have a positive environmental impact from adoption. IPM adopters have reduced EIQ field use, health and environmental effects. In the second scenario, we assumed that all farmers have access to credit, which would reduce the value of EIQ field use by 28.38% among the adopters. The results showed that access to credit does have an impact on health and environmental effects since all adopters gained from strategy whether they had access to credit or not. Use of protective clothes reduced health and environment effects for IPM adopters.

TABLES

Table i: Farmers perceptions on pesticide risks (Source: Field survey, 2014)

Perceptions	Overall (n=371)		Non-IPM participants(n=165)		IPM Participants (n=206)	
Health	Freq.	%	Freq.	%	Freq.	%
Large Risk	150	39.4	65	39.4	85	41.3
Medium Risk	98	22.4	37	22.4	61	29.6
Small Risk	57	17.6	29	17.6	28	13.6
Very Toxic	42	13.9	23	13.9	19	9.2
No risk at all	24	6.7	11	6.7	13	6.3
Environment	Freq.	%	Freq.	%	Freq.	%
Large Risk	106	25.5	42	25.5	64	31.1
Medium Risk	95	26.1	43	26.1	52	25.2
Small Risk	97	23.1	38	23.1	59	28.6
Very Toxic	12	4.9	8	4.9	4	1.9
No risk at all	61	20.6	34	20.6	27	13.1

Source: field survey data 2014

Table ii: Probit models for determinants for IPM adoption (Source: Field survey, 2014)

	Independent probit		Joint estimated probit	
Variables	Coefficient	SE	Coefficient	SE
Household size (count)	-0.236	0.152	-0.128	0.148
Years in Mango farming (years)	0.214***	0.075	0.131*	0.068
Household head's age (years)	-0.000**	0.000	-0.002***	0.000
Agricultural land owned (acres)	0.226**	0.104	0.064	0,122
Household head's gender (dummy)	0.050	0.207	-0.022	0.182
Extension contact (dummy)	-0.071	0.156	-0.070	0.163
Protective clothe usage (dummy)	0.179	0.241	0.167	0.142
Group membership (dummy)	-0.479***	0.169	-0.486**	0.156
Credit services access (dummy)	0.001	0.177-	0.043	0.161
Irrigation water access (dummy)	0.326**	0.153	0.143	0.138
Labour management (ratio)	0.002	0.005	0.001	0.005
Mango production trees (count)	0.505***	0.741`	0.516***	0.738
Monthly income (Kshs)	-0.010	0.018	-0.000	0.016
Educational level (school years)	-0.004	0.019	0.003	0.014
Constant	-1.067	0.609	-1.167**	0.574
Total observations		370		370

NB: Statistical significance at 0.01(***), 0.05(**) and 0.1 (*)

Source: field survey data 2014

Table iii: Full information maximum likelihood parameter estimates for health and environmental effects (Source: Field survey, 2014)

	IPM Participants		IPM Non-participants	
Variable	Coefficient	S.E	Coefficient	S.E
Household size (count)	0.389	0.264	-0.435*	0.254
Years in mango farming (years)	-0.019	0.125	0.012	0.105
Household head age (years)	0.000***	0.000	-0.000	0.000
Agricultural land owned (acres)	-0.182	0.233	0.135	0.194
Household head age(dummy)	0.435	0.327	-0.319	0.288
Extension officers access (dummy)	0.177	0.299	0.286	0.267
Protective cloth usage (dummy)	0.009	0.262	-0.379	0.239
Group Membership (dummy)	0.562**	0.269	0.083	0.291
Credit services access (dummy)	0.070	0.278	0.244	0.265
Irrigation water access(dummy)	-0.411	0.258	0.206	0.243
Labor Management(ratio)	-0.021*	0.012	0.002	0.005
Mango production trees (count)	-0.730**	0.131	-0.378**	0.167
Constant	2.717	0.972	4.995	0.937
$\ln\sigma_1$, $\ln\sigma_0$	0.693(0.059)***	0.355(0.061)***		
$\rho_1\rho_0$	-1.89(0.45)***	-0.179(0.268)		
LR test of independent questions		35.25**		
Total observations		371		
Log likelihood		-335.287		

***, **, * mean values are significant at 1%, 5% and 10% respectively

Source: field survey data 2014

Table iv: Treatment effects of IPM technologies (Source: Field Survey, 2014)

	Observations	Adopters EIQ Field use	Non-Adopters EIQ Field use	Net change (%)
All mango farmers	371	5.65	47.12	-6.81***
By land holding				
Mango farmers<1 acres	18	0.10	74.17	-160.45***
Mango farmers 1-2 acres	100	11.64	45.39	-14.17***
Mango farmers>2 acres	253	5.21	43.09	-31.65***
Protective Clothes use				
Yes	205	6.06	44.16	-27.21***
No	165	5.23	49.62	-31.53***
Credit Facilities Access				
Yes	95	5.81	57.19	-28.38***
No	276	5.75	43.92	-28.67***
Attend ICIPE's Training				
Yes	234	5.27	0	-31.29***
No	137	7.36	35.244	-22.40***

***, **, * mean values are significant at 1%, 5% and 10% respectively

Source: field survey data 2014

Table v: Environmental Impact Quotient Field Use (Source: Field survey, 2014)

Active Ingredient	Trade Name	EIQ F	EIQ C	EIQ E	EIQ T	Rate (kg/acre)	EIQ Field use overall	EIQ Field non-participants	EIQ Field use participants	T value	P value	% of farmers using	Vol.kg
Thiamethoxam (U)	Actara	10.35	12.03	77.52	33.3	0.12	5.75	3.55	2.19	0.7891	0.2341	0.81	1.14
Methomyl (IB)	Agrinate	6	11	75	31	0.28	277.38	221.12	56.27	0.2389	0.8805	6.20	452.31
Propineb (1II)	Antracol	6	5.78	14	18.34	0.27	30.93	0.10	30.82	1.2615	0.5807	6.20	534.42
Triadimefon (III)	Bayleton	12.15	15.15	53.57	33.3	0.25	277.31	105.04	172.27	-2.9994***	0.0033	34.50	134040.8
Beta-Cyfluthrin (II)	Bulldock	9	4	69	27	0.21	634.28	550.42	83.86	2.6674***	0.0087	33.96	69418.38
Copper Oxychloride (III)	Copper	108	19	76	67.7	0.20	557.61	512.49	45.12	3.0990***	0.0035	12.12	9444.32
Cypermethrin (II)	Cyclone	9	4	69	27	0.14	22.75	12.14	10.61	-1.5302	0.1482	4.58	173.3091
Dimethoate (II)	Danadim	72	9	141	74	0.22	76.91	46.79	30.11	-0.5301	0.6104	2.67	35.25
Deltamethrin (II)	Decis	6	3	68	26	0.26	0.58	0.21	0.37	0.2350	0.4325	2.43	101.10
Dimethoate (II)	Twigathoate	72	9	141	74	0.21	946.16	794.15	152.01	1.3425	0.7856	8.63	2855.765
Mancozeb (U)	Dithane	12	3	29	44	0.40	532.53	515.95	16.56	0.0955	0.92566	2.43	90.54
Lambda Cyhalothrin (II)	Karate	21	3	106	44.17	0.09	7.96	7.12	0.84	0.1144	0.9100	6.20	84.38
Methomyl (IB)	Weiling	6	11	75	31	0.31	56.45	38.27	18.18	-1.9925*	0.0866	2.42	69.92
Propineb (III)	Milraz	6	6	14	9	0.17	1.54	0.00	1.54	0.8745*	0.0534	1.35	5.07

Acephate (III)	Orthene	15	12.5	47.15	24.88	0.19	16.81	12.59	4.22	0.7131	0.4875	4.58	230.25
Carbendazim (U)	Rodazim	25	40.5	86	50.5	0.26	490.33	485.54	4.79	-0.7419	0.4752	3.23	28.57
Alpha-cypermethrin (II)	Tata alpha	21	3	106	44	0.30	39.62	39.62	0.00	0.1451	0.8862	5.39	34.38
Sulphur (U)	Thiovit	10	6	120	45.5	0.32	24.09	14.12	9.97	0.7117	0.4835	7.00	1427.01
Imidacloprid (II)	Thunder	6.9	10.35	92.88	36.71	0.21	36.36	35.51	0.85	-1.1227	0.2722	7.27	435.39
Thiophanate-Methyl (U)	Topsin	16.2	15.3	39.95	23.83	0.10	14.32	11.30	3.02	-0.58546	0.5796	2.16	2.87
	Total						4049.67	3410.27	639.40	-7.7660***	0.000	100	219465.20

NB: Statistical significance at 0.01(***), 0.05(**) and 0.1 (*)

CONCLUSIONS

The need for sustainable and environmental friendly agriculture has promoted invention of new techniques leading to increased mango production and access to lucrative markets. There is no study that has estimated health and environmental effects of IPM technologies. In regards, this gap can be bridged by estimating health and environmental effects of IPM technologies. Based on primary survey data of mango farmers in Meru County, we find that farmers with less than one acre of land had more benefits in adopting IPM technologies. The results indicated that IPM technologies have positive benefits on health and environment.

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4. Parallel Session 3 : Crop Management, Biotechnology and Climate Change

4.1 Bostrichidae beetles associated with *Acacia xanthoploea* at Kenyatta University and Mitaboni in Nairobi and Machakos Counties, Kenya

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ABSTRACT
The Naivasha thorn tree *Acacia xanthoploea* (Fabaceae: Mimosoideae) is an important tree found in areas with high water tables in Kenya. They are grown for foliage, timber, shade and rehabilitation of soils. Its production is threatened by both abiotic and biotic factors especially the insect pests which are a major cause of losses. The invasive powderpost beetle is one of the insect pests posing a major threat to acacia and other forest resources in the Country. Despite this, very little is documented on the powderpost beetles, their damage and natural enemies in Kenya. The study was conducted to evaluate the occurrence and damage of powderpost beetles in the family Bostrichidae on *Acacia xanthoploea.* Infested wood samples of *A. xanthoploea* with fresh exit holes were collected from three sites in Kenyatta University (KU) and Mitaboni Kenya. The samples were placed in clear plastic buckets and taken to the laboratory where they were kept at ambient temperatures and observed daily for emergence of powderpost beetle. The beetles were collected every three days, identified and recorded. The experiment was replicated four times and data collected twice a week for 6 months. Data on abundance was subjected to analysis of variance using SAS. Over 5,850 and 4,691 insects were recovered where 2,187 and 3,097 were Bostrichidae which accounted for 37% and 66% in KU and Mitaboni, respectively. A total of 12 species of powderpost beetle in the Family Bostrichidae were recovered which included *Sinoxylon ruficorne, S. doliolum, Xylion adustus*, *Xyloperthodes nitidipennis*, *Xyloperthella picea, Xylopsocus castanoptera*, *Lyctus brunneus, Heterbostrychus brunneus, Xylopsocus sp.*, and *Dinoderus gabonicus.* The most abundant species were *Xylion adustus* in KU with 1,915 beetles accounting for 88.4% and *Sinoxylon ruficorne* in Mitaboni with 1,050 beetles comprising 33.9%. *Sinoxylon ruficorne* was only recorded in Mitaboni while 2 specimens of *D. gabonicus* were found in KU only. The mean number of exit holes on *A. xanthoploea* differed significantly between sites which coincided with the damage by the beetles. Therefore, there is urgent need to document the abundance of powderpost beetles in Kenya and quantify the damage caused. Since a number of parasitoids were recovered, there is need to conduct more studies and document the species diversity, parasitism rates and efficacy trials as possible bio-control agents.
Key words: Bostrichidae, powderpost beetles, species, abundance, damage

INTRODUCTION

Acacia xanthophloea belonging to the pod bearing plant family Fabaceae, subfamily Mimosoideae is commonly known as sulphur bark, Naivasha thorn or fever tree in English, Mgunga in Swahili, and Murera in the Kikuyu dialect of Kenya. There are over 40 species, subspecies and varieties of *Acacia* represented in Africa. The fever tree is an attractive, semi-deciduous to deciduous tree approximately 15 to 25 meters tall, with open rounded to spreading or flattish crown which is sparsely foliated. They have characteristic lime green to greenish-yellow bark is smooth, slightly flaking and coated in a yellow powdery substance with straight white paired thorns, up to 7 cm, white and clustered leaves on short lateral shoots of 4-6 pairs of pinnae. Flowers are axillary clusters of pale yellow spherical heads while the pods are straight, papery with a wavy margin and indehiscent (Dharani *et al*., 2006; Gathuru, 2011).

Acacia xanthophloea is native to Botswana, Kenya, Malawi, Mozambique, Somalia, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe (Orwa *et al*., 2009). It grows in semi-evergreen bush land and woodland in areas with a high groundwater table near swamps, riverine forests or at lakesides and often forms dense stands in seasonally flooded areas. It is able to tolerate several degrees of frost. Other than growing naturally, the species is grown for foliage and pods provide food for livestock, young branches and leaves are eaten by elephants, leaves and pods by giraffes and velvet monkeys (Dharani *et al*., 2006). It has been used in apiculture as the trees produce good bee forage, source of firewood, timber, shade, nitrogen fixing, acts as live fences, provide nesting sites for birds, (Orwa *et al*., 2009) and for charcoal production especially in areas of its widespread occurrence (Okello *et al.,* 2001). Today, the species is also being grown as an ornamental tree. The roots and the bark of stem have been used as medicine against malaria due to their pharmacological properties (Orwa *et al*., 2009). They have also been used in rehabilitation of limestone quarries in Athi River, Kenya (Gathuru, 2011) and to curb soil erosion. This results in the increase of biodiversity of plants, animals and restoration of nature.

The species are faced by a number of biotic and abiotic constraints that interfere with the good prospects from the tree. They are always under the influence of biotic factors such as pests and diseases and abiotic factors such as drought, water-logging (Wargo, 1996; Hakeem *et al*., 2012). This makes them more susceptible to attack by wood boring insects (Thomas *et al*., 2002) which are generally xylophagous. Many xylophagous insects have symbiotic protozoa and/or bacteria in their digestive system which assists in the breakdown of cellulose. Though the vast majority of powderpost beetles are ecologically important and economically benign, some species are economic pests attacking relatively healthy trees, untreated wood, and downed trees in lumber yards. However, some are invasive species that threaten natural forest ecosystems.

Plant-insect interactions are quite common in nature and arthropod pests cause direct damage to the plants or their products. Some of the key pests include wood boring beetles in the family Lyctidae or true powder post beetles, Anobiidae or deathwatch beetles, and Bostrichidae or false powder post beetles among others. There are approximately 570 species in 89 genera worldwide (Lawrence, 2010), with over 40 species of insects documented to be associated with *Acacia* species. Bostrychidae is the most notorious Family in locating and infesting freshly cut wood (Orwa *et al*., 2009). They are often referred to as powderpost beetles because of their ability to reduce wood to a thin external shell covering the frass produced by the boring activities of the larvae and adults (Beaver *et al.,* 2011). Generally, Bostrichid beetles prefer to infest dry wood with relatively low moisture content between 8 and 30% (Lek-Uthai *et al*., 1982; Ivie, 2002).

Despite the risk of pest introduction from traded agricultural products being manageable, many biological invasions continue to occur worldwide EEA (2012). Some species have been dispersed around the world by trade in timber and timber products (Beaver *et al*., 2011) and many invasions are unavoidable due to the pest characteristics (Lopes-da-Silva *et al*., 2014). The powderpost beetles attack the wood at all stages from log to seasoned wood and finished products (Findlay, 1985). They have been recorded in forests, timber depots, sawmills and furniture industries, buildings, seasoned timber, wood artefacts, boxes and packing cases (Ivie, 2002). They obtain nutrition from starch, enabling many species to utilize almost any dry wood material from enormous host range including trees, shrubs, herbaceous plants and bamboo (Ivie, 2005; Fihlo *et al*., 2006). Most species are polyphagous and attack a wide variety of host plants in many different families (Beaver *et al*., 2011). They prefer wood with high starch content (Creffield, 1991; Peters *et al.,* 2002; Akhter, 2005; Allen, 2005) with relatively low moisture, or dried wood (Gerberg, 1957; Cookson, 2004; Ivie, 2002). However, some species are specialist and tend to be confined to a single genus or species of a host plant.

The powderpost beetles, the auger beetles or the horned powderpost beetles (Coleoptera: Bostrichidae) are serious xylophagous pests of trees, forest products, silviculture, agricultural crops and stored vegetable products in most regions of the world, especially in tropical countries (Nair, 2007; Liu *et al*., 2008; Lawrence, 2010). Polyphagous pests inflict greater damage on plants in mixed vegetation systems compared to monophagous pests. Some species have also become pests of stored grain and root crops (Fisher, 1950; Lawrence, 2010). However, studies of their ecology are rare. Most of these pests have been introduced accidentally from their native countries possibly via wooden crates or pallets for cargo shipment. The genus *Sinoxylon* is native to Europe, the Afro-tropica; region, the Australian region, the Near East, the Neartic, the Neoptropical region, North Africa and the Oriental region (Borowski and Wegrzynowicz, 2007; Beaver *et al*., 2012) with over 52 species in within the genera. It is one the most intercepted species in many countries (Price *et al*., 2011; Kevin *et al*., 2012). It also commonly found in tropical areas, especially in the arid regions, where they damage wide range of trees (Bushara, 1981).

The powderpost beetles have a very wide host range and attack any kind of wood both softwood and hardwoods with suitable moisture and starch content. However, they have preference for hardwoods due to presence of pores that enable easy penetration and by larvae and laying of eggs by adults. Some of the families include Ullmaceae, Euphorbiaceae, Lauraceae, Legumnoceae, Mimosaceae, Dipterocarpaceae, Anacardiaceae, Rubiaceae and Poaceae Ulma-Euphorbiaceae, Lauraceae, Dipterocarpaceae, minosaceaae, Anacardiaceae, Rubiaceae among others (Fisher, 1950; Poggie *et al*., 1994; Peres Filho *et al*., 2006). *Sinoxylon* species are particularly important pests of trees, wood and bamboos (Fisher, 1950; Teixeira *et al*., 2002). *Sinoxylon conigerum* has been recorded attacking rubber wood *Hevea brasiliensis* Müll., pigeon pea *Cajanus cajan* (L.), mango tree *Mangifera indica* L., cassava stem *Manihot esculenta* Crantz, fallen trunk of flamboyant *Delonix regia* (Bojer), cotton dry roots *Gossypium hirsutum* L., branches of guava *Psidium guajava* L., and teak (*Tectona. grandis*) (Balasubramanya *et al.*, 1990; Binda and Joly, 1991; Tomimura, 1993). Fischer (1950), recorded *S. conigerum* attacking *Adina cordifolia* Benth., and Hook., *Albizzia* amra (Roxb.) Boiv., *Holoptelea integrifolia* (Roxb.) Planch., *M. indica, Shorea robusta* Gaertn., *Terminalia bialata* (Roxb.) Steud., *Terminalia myriocarpa* Van Heurck & Mull. Arg., *Grewia tiliaefolia* Vahl,. *Sinoxylon senegalense* is the most notorious pest of the white thorn acacia *Acacia seyal* (Fabaceae *Mimosoideae)* native to Kenya (Orwa *et al*., 2009). *Acacia tortilis* is also infested by *Sinoxylon crissum* and auger beetle *S. anale*. *Sinoxylon anale* and *S. unidentatum* are the most destructive powder post beetles of rubber sawn wood in southern Thailand (Halperin and Geis, 1999; Liu *et al*., 2008). *Sinoxylon unidentatum* has also been recorded attacking Ulma-Euphorbiaceae, Lauraceae, Dipterocarpaceae, minosaceaae, Leguminoseae, Anacardiaceae, Rubiaceae (Fisher, 1950, Poggie *et al*., 1994, Peres Filho *et al*., 2006). *Sinoxylon anale* is a significant pest of agricultural, forestry and forest product industries as they are very harmful to trees, bamboos and wood.

The false powderpost beetle *Xylopsocus* species has been recorded in the wood of *Morus alba* L. trunks of “Kimoungoue” in east Africa, bamboo, litchi *Litchi chinensis* Sonn., and grape *Vitis* sp. in Brazil (Lesne, 1924; Fisher, 1950). Miller (1934) recorded *X. capucinus* attacking *piquia* (*Caryocar villosum* Pers.), rambutun *Nephelium lappaceum* L., rubber *Hevea brasiliensis* (Willd. ex A. Juss) Muell. Arg.), *Dipterocarpus* sp., *Derris* sp., guava *Psidium guajava* L., *Casuarina equisetifolia* J.R. Forst. & G. Forst., *Syzygium malaccensis* (L.) Merrill & L.M. Perry, cinnamon *Cinnamomum zeylanicum* Blume, *Indigofera anil* L., cashew nut *Anacardium occidentale* L., durian *Durio zibethinus* J. Murr., *Tephrosia candida* DC., *Gardenia jasminoides* Ellis, tamarind *Tamarindus indica* L., *Hibiscus Rosa sinensis* L.

Because of the ability of the larvae and some adults to reduce wood into a powdery frass, the beetles are of considerable economic importance to forestry and the wood-using industries, especially in tropical countries (Liu *et al*., 2008; Beaver *et al*., 2011). The damage is typically caused by the larvae and adults boring in the stems, branches, twigs of dead, damaged or stressed host (Halperin and Geis, 1999; Peters *et al.*, 2002; Nair, 2007; Liu *et al.*, 2008)). One of the most characteristic signs of infestation are the exit holes produced by the adults beetles at emergence which are perfectly circular and the diameter depends on the wood-boring species (Herald *et al*., 2009). Other signs include death, dieback, exudation of gummy sap or resin and early branching depending on the infested trees, degree of resistance and the beetle species. They infest weakened or dead trees and branches and gradually render them into fine dust. The Bostrichid beetles prefer to infest dry wood with relatively low moisture content between 8 and 30% (Lek-Uthai *et al*., 1982; Ivie, 2002).

The female adults deposit eggs in cracks, crevices, pores or old emergence holes in wood, or in tunnels made by the females. The eggs takes 1 to 2 weeks to hatch into a tiny larva that burrows and tunnel through the host tissues making extensive frass-filled galleries (Obeid, 1998). The larva undergoes a number of instars, tunnel through the host tissues making extensive frass-filled galleries (Beaver *et al*., 2011) and burrows toward the surface to pupate. The larval period lasts between 7 to 10 weeks while the pupa period can last 3 to 4 weeks. After the adult emergence, it continues the tunnel to the surface making the exit holes, mates and the females return to the wood to lay eggs. The females are usually larger than the males (Bushara, 1979; El Obied, 1998). The life cycle may range from 3 months to years depending temperatures, relative humidity, type and species of the powder post beetle. In the tropics, there are usually one to four overlapping generations per year (Liu *et al*., 2008a).

According to Monks (2000), there are two practical usefulness of the study of local species that have unique properties. They are first for the protection and use of biodiversity, and secondly for assessment of the impacts that may arise due to changes in the environment. Some components that determine a species as indicators are the diversity of taxonomy, abundance, distribution, the role of these types, and the extent to which these types are easily recognizable (Monks 2000). Some families also play an important ecological role in decomposition and nutrient cycling in forest communities (Harmon *et al*., 1986).

A number of appropriate management strategies have been used in the mitigation of the powderpost beetles. They include delimitation of infested areas, exclusion and prevention through regulatory restriction of movement of pest infested wood or plant materials, moisture control, wood replacement, surface insecticide treatment, physical destruction of infested trees, and fumigation. Biological control via introduction and release of natural enemies collected from native ranges (Liu *et al*., 2003; Taylor *et al*., 2011). The selection of management strategies depends on a number of factors such as severity of infestation, area being attacked, potential for re-infestation and treatment costs.

Predators in the family Cleridae, Histeridae, Melyridae, Trogossitidae) (Lesne, 1906, 1924; Bahillo de la Puebla *et al*., 2007; Kolibáč, 2013, Lawrence and Slipinski, 2013). Predation by birds also occurs (Bahillo de la Puebla *et al*., 2007). Hymenopteran parasitoids especially Pteromalidae and Braconidae are known to parasitize beetles in the Family Bostrichidae (Gerstmaier *et al*., 1999; Bahillo de la Puebla *et al*., 2007; Yu *et al*., 2012; May, 2015; Noyes, 2015). According to Deepthi and Ramavedi (2012), ectoparasitoids in the family Passandridae are known to attack the powderpost beetles. Few studies have been conducted on biological control because predators and parasitoids are not known to have a significant effect on beetle populations in natural conditions (Katiyar and Sharma, 1987; Edde, 2012; May, 2015). By contrast, ecosystem services related to biotic interactions, such as pollination or pest control, could be predominantly driven by species richness (Galiballdi *et al*., 2013).

Scanty information is available about the insects associated with the multipurpose trees and shrubs that are gaining greater economic importance as components of agroforestry systems. Therefore, the study aims to investigate the abundance, species composition, diversity of the powderpost beetles and their associated natural enemies both predators and parasitoids from *A. xanthoploea* growing around Kenyatta University and Mitaboni. The beetles were chosen because they are the most abundant and diverse group of insects in the environment as observed by Speight *et al.* (2008). In addition, the dynamics of the powderpost beetles and their natural enemies are governed by the complexity and composition of the agroforestry system.

MATERIAL AND METHODS

Study sites

The survey was conducted in May 2016 from Kenyatta University (KU) and Mitaboni in Nairobi and Machakos County. Kenyatta University is located 15 Kilometers North of Nairobi at 1°11´ S and 36°55´ E at an altitude of 1,600 meters above sea level. The area experiences bimodal rainfall between 1,000-1,400 mm annually with average temperature range of 18-24°C and has clay murram soils. Mitaboni is 17 km North west of Machakos town at 1°21´ S and 37°14´ E at 1,525 m asl. The area receives annual rainfall between 600-900 mm, average temperatures of 27°C and the soils are comprised of clay and murram.

Evaluation on abundance of powderpost beetles of *Acacia xanthoploea*

Three sites from KU and Mitaboni where *Acacia xanthoploea* was growing were identified for the studies. Purposive sampling was used to collect the dry wood with inactive exit holes, active or freshly bored holes by the powderpost beetles and those showing damage symptoms (sawdust coming out). The wood was transversely cut into pieces measuring 15cm long 10 cm diameter or equivalent volume as describe by Sittichaya and Beaver (2009) and Kangkamanee (2011) and placed in 20 L plastic containers (Plate 2). The samples were taken to Kenyatta university Biotechnology laboratories and kept at ambient room temperatures of 23±1°C, 60±10% RH, and 12 L: 12 D photoperiod and observed for a period of 8 months until no more beetles emerged. The emerging and positively phototropic adults of the powderpost beetles were collected every two days, placed in petri dishes observed under the dissecting microscope where the individual families and species of the powderpost beetles were separated using morphological and taxonomic characteristics, identified and numbers recorded. The Bostrichidae were identified as described by Wisut *et al.* (2009) and Liu *et al*. (2008a; 2016). The recent taxonomic nomenclature was adopted in the identification and confirmation of the jewel beetles in the family Buprestidae (Bellamy, 2013). The specimens were preserved in 95% ethanol and taken to the National Museums of Kenya (NMK) for confirmation while Bostrichidae were sent to Taiwan for confirmation by Dr. Liu lan-Yu.

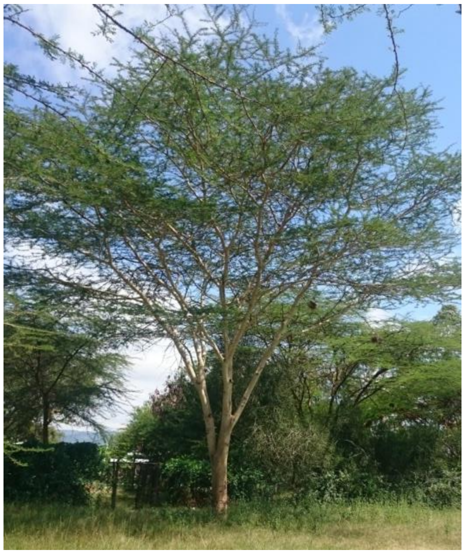

Plate 1: Naivasha thorn tree *Acacia xanthoploea* (source Kahuthia R.)

Evaluation of number of exit holes of the powderpost

The cut pieces of *A. xanthoploea* were placed in well ventilated plastic buckets with lids and taken to Kenyatta University laboratories where they were kept at ambient room temperatures at 23±2C° at 50-65% RH. The number of active exit holes or freshly bored holes by powderpost beetles was counted and recorded (Plate 1).

Plate 2: Exit holes of powderpost beetles on *Acacia xanthoploea* branch (source Kahuthia R.)

Data analysis

The number of beetles was subjected to one way Analysis of Variance (ANOVA) to estimate the mean infestation. The infestation density on acacia from each region at different collection dates will be computed. The data will be compared using the Mann–Whitney U test and Kruskal–Wallis test as described by Zar (1984) to determine any difference in infestation densities within time and regions.

Results

Families of powderpost beetles recorded on *Acacia xanthoploea*

Over 5,850 and 4,691 powderpost beetles were collected and examined from *A. xanthoploea* collected from KU and Mitaboni, respectively. A total of 17 and 13 families of the powderpost, wood boring beetles in the order Coleoptera and Sub-order Polyphaga were recovered from Nairobi and Mitaboni, respectively. Other than the powderpost beetles, predators and parasitoids were also recorded from the study sites. The families included Bostrichidae, Buprestidae, Bothridiidae, Curculionidae, Cleridae, Cerambycidae, Chrysomelidae, Ciidae, Colydiidae, Dermestidae, Histeridae, Lyctidae, Tenebrionidae, Staphylinidae, Scolytinae, Silvanidae, Laemophloeidae, and Elateridae (Tables 2 and 3). Most of the powderpost beetles were mainly from the Families Bostrichidae, Buprestidae, Curculionidae, Lyctidae and Histeridae. Kenyatta University recorded 16, 6 and 6 species of Bostrichidae, Curculionidae and Lyctidae, respectively. However, 14, 6 and 5 species of the families Bostrichidae, Lyctidae and Curculionidae were obtained from Mitaboni, respectively.

Bostrichidae was by far the most rich-species family in the order Coleoptera followed by Curculionidae. A total of 2,187 and 3,097 powderpost beetles were Bostrichidae accounting for 37% and 66% in KU and Mitaboni, respectively (Table 1). At least 16 and 14 species of Bostrichidae powderpost beetles were recorded from KU and Mitaboni accounting for 51.79% and 73.49%, respectively (Tables 2 and 3). Other dominant families in KU included Lyctidae, Staphylinidae and Buprestidae.

Table 1: Percent contribution of the family Bostrichidae

Study sites	Beetles collected	Bostrichidae	Percent contribution
KU	5850	2187	37.4
Mitaboni	4691	3097	66

Table 2: Powderpost beetle families recovered from *Acacia xanthoploea* at Kenyatta University

Families	No of species	Abundance	Percent (%)
Bostrichidae	16	2,189	51.79
Curculionidae	6	863	20.42
Lyctidae	6	307	7.98
Staphylinidae	2	353	8.35
Buprestidae	4	201	4.76
Cerambycidae	3	127	3.00
Anobidae	2	109	1.86
Laemophloeidae	2	27	0.64
Dermestidae	2	2	0.04
Silvanidae	1	1	0.02
Scolytidae	1	1	0.02
Bothrideridae	2	16	0.38
Colydiidae	1	23	0.54
Others	4	13	0.31

Table 3: Powderpost beetle families recorded from *Acacia xanthoploea* in Mitaboni

Families	No of species	Abundance	Percent (%)
Bostrichidae	14	3,097	73.49
Curculionidae	5	898	21.31
Lyctidae	6	135	3.20
Buprestidae	1	2	0.05
Anobidae	1	1	0.02
Cerambycidae	2	11	0.26
Dermestidae	1	33	0.76
Silvanidae	1	2	0.05
Staphylinidae	3	21	0.5
Bothrideridae	1	2	0.05
Others	5	5	0.17

Abundance of Bostrichidae species recovered from *A. xanthoploea* from KU and Mitaboni

Bostrichidae species included *Sinoxylon ruficorne* Fåharaeus*, S. doliolum* Lesne*, Xylion adustus* Fåharaeus, *Xyloperthodes nitidipennis* Murray, *Xyloperthella picea* Oliver, *Xylopsocus castanoptera* Fairmaire, *Lyctus brunneus* Stephens, *Heterbostrychus brunneus* Murray, *Xylopsocus sp.*, and *Dinoderus gabonicus* Lesne. The most abundant species in KU were *X. adustus* followed by *S. doliolum* with 1,915 and 137 beetles accounting for 88.4% and 6.23%, respectively (Table 4). In Mitaboni, the abundant species were *S. ruficorne, S. doliolum, X. picea* and X. *nitidipennis* accounting for 33.9%, 19.9%, 15.5 and 10.3%, respectively. The species *Sinoxylon ruficorne* was only recorded in Mitaboni while *D. gabonicus* in KU.

Table 4: Abundance of Bostrichidae species recorded from *Acacia xanthoploea* at Kenyatta University and Mitaboni

No of species	Kenyatta University		Mitaboni	
	No. beetles	Percent (%)	No. beetles	Percent (%)
Sinoxylon ruficorne	-	-	1,050	33.9
Xylion adustus	1,915	88.4	108	3.5
Sinoxylon doliolum	137	6.23	615	19.9
Xyloperthella picea	12	0.3	480	15.5
Xyloperthodes nitidipennis	98	2.2	319	10.3
Xylopsocus castanoptera	2	0.05	6	0.2
Lyctus brunneis	93	1.6	20	0.7
Dinoderus gabonicus	-	-	2	0.06

Powderpost beetle damage on *Acacia xanthoploea*

There was significant difference (df=5,122; f=6.32; $P<0.0001$) on the mean number of exit holes made by the powderpost beetles on the pieces of wood of *A. xanthoploea*. It was also observed that samples from Mitaboni had significantly higher number of exit holes compared those recorded at Kenyatta University (Table 6). The mean number of exit holes was comparable in all the three sites at KU. In Mitaboni, site 2 had the highest number of exit holes while in KU, site 1 had the lowest of 66.4 and 31.1, respectively. The young adults remain tunneling and feeding in the wood for several days before emerging through small circular holes they make in the wood. Upon removal of the bark, the damage was exhibited as observed on plates 3, 4 and 5. Most of the pupae and adults are found just below the bark and cause significant damage on the wood reducing it to a powder.

Table 6: Mean ±SE number of exit holes of powderpost beetles on *Acacia xanthoploea* at Kenyatta University and Mitaboni

Region	Site	N	Number of exit holes
Kenyatta University	1	19	31.1±4.7c*
	2	15	39.9±6.1bc
	3	20	32.3±4.9c
Mitaboni	1	33	41.7±3.7bc
	2	17	66.4±7.1a
	3	24	59.3±6.7ab

*Means followed by the same letter in the same column are not significantly different at $P\leq0.05$

Plate 3: Pupae of powderpost beetles on *Acacia xanthoploea* (source Kahuthia R.)

Figure 4: Adult powderpost beetles on *Acacia xanthoploea (*Source Kahuthia R.)

Plate 5: Damage on *A. xanthoploea* by powderpost beetles

DISCUSSION

A number of families were recovered from wood samples of Acacia xanthoploea in KU and Mitaboni. They included Bostrichidae, Buprestidae, Histeridae, Curculionidae, Lyctidae, Chrysomelidae, Dermestidae, Tenebrionidae, Staphylinidae, Cleridae, Cerambycidae, Silvanidae, Laemophloeidae, Ciidae and Elateridae. Similar observations were made by Kuria *et al*. (2010) who recorded rich beetle communities from *Acacia drepanolobium* in Kenya which comprised of 13 beetle families mainly Curculionidae, Anthicidae, Cleridae, Buprestidae, Cerambycidae, Bostrichidae. These results are also comparable with those of Speight *et al.* (2008) who found high species richness with Bostrichidae being the most abundant and diverse group of insects in the environment. The abundance and diversity of the families on the *A. xanthoploea* were well adapted to the prevailing climatic and edaphic conditions in both KU and Mitaboni where the temperatures range between 21°C to 30°C. The diverse families and species could be related to high nutritional value from the species. Ivie (2005) and Fihlo *et al*. (2006) reported that the powderpost beetles obtain nutrition from starch, enabling many species to utilize almost any dry wood material from enormous host range including trees, shrubs, herbaceous plants and bamboo.

The preliminary study shows that powderpost beetles in the order Coleoptera suborder Polyphaga were the most abundant and diverse group of insects recorded in wood of *Acacia xanthoploea* from both Kenyatta University and Mitaboni. *Xylion adustus* was the most dominant species at Kenyatta University accounting for 52.3% of the total beetle recovered during the study. The species has also been reported in Tanzania, Malawi, Southern Africa and South Africa. However, there is no documentation on their abundance and species they infest in Kenya.

Other than Bostrichidae, Buprestidae beetles were recorded with more abundant *Agrilus* species being recorded in KU accounting for 5.5% in KU while only 4 specimens were recorded in Mitaboni. Studies conducted by Vladimir and Georgi (2013) indicated that the Buprestidae fauna has over 429 species in Kenya. This additional information on Buprestidae is useful as per findings of Salikan and Georgi (2013) who also suggested the need for further detailed studies in order to enrich the knowledge on numbers and distribution of the buprestid species in Kenya

It was observed that *S. ruficorne* and *S. doloilum* were the most abundant species in Mitaboni and accounted for over 47.8% and 17%, respectively. Singh (1995) also recorded *Sinoxylon ruficorne* on *Acacia mearnsii* in Kenya. However, its abundance was not quantified. The auguer beetle *S. ruficorne* were also found infesting cassava roots in Mozambiques, Nigeria and South Africa while *S. doliolum* is distributed in Tanzania in Africa (Hagstrum, 2009). In addition, *X. castanoptera* has also been recorded in East Africa, Madagascar and Mauritius. *Dinoderus gabonicus* which is usually distributed in West Africa was recovered from the *A. xanthoploea* at Kenyatta University.

The powderpost beetles caused so much damage on *A. xanthoploea* which is one of the major trees which local population utilizes for timber, firewood, fencing and apiculture. There is need to conduct more studies to evaluate the damage of powderpost beetles can cause especially where the population use the timber for building with very little or no preservation. Similar findings were observed on Beetles belonging to the family Lyctidae are amongst the most important degraders of sapwood from seasoned hardwoods worldwide. With impending timber shortages and concerns over depleting forest resources in many countries, intense efforts have been made to maximize utilization of forest resources including lesser known or underutilized species, lower grade timbers and also to encourage a more widespread use of sapwood in timber products. Utilization of such materials which are often of lower resistance to wood degrading insects has led to greater prominence of *M. rugicollis.*

CONCLUSION AND RECOMMENDATIONS

In conclusion, these preliminary studies show that there are numerous families and species diversity of the powderpost beetles infesting the *A. xanthoploea* at Kenyatta University and Mitaboni areas of Kenya. Given the distances between these two sites, there is indication that the problem could widespread in the country. There is thus an urgent need to conduct more research on the biology, ecology, distribution, abundance and species diversity of powderpost beetles in areas of Kenya where *A. xanthoploea* are found. Since a number of predators and parasitoids families from were also recovered in the study, more investigations on host specificity and efficacy of these parasitoids needs to be investigated so as to determine species that could be used in classical biological control or augmentation in order to keep the powderpost beetles below economic threshold level (ETL).

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4.2 Effect of Poly culture cropping on infestation of maize by the vectors of Maize lethal necrosis viruses in Bomet county of Kenya

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ABSTRACT

The presence of Maize lethal necrosis disease (MLND) has constrained maize production due to a co-infection of maize by the two viruses. This study was carried out to determine the potential of various cropping systems in managing vectors of maize lethal necrosis disease causing viruses. Treatments included companion crops elephant grass, coriander, pearl millet and sorghum grown as intercrops and border crops with maize. A randomized complete block design was used with four replicates for two seasons in Bomet County. Mean vector counts was analysed using ANOVA and means separated by LSD. The cropping system had no effect on thrips and aphids infestation as well as MLND severity on maize. Maize grown as a monocrop registered the highest significant disease incidence (66%). The one surrounded by sorghum border significantly registered higher cob percentage fill (79%), cob weight (126g) number of good seeds (213) as well as fresh weight (59g). Corn thrips mean infestation on companion crops levels was significantly higher on the control (maize) (46) followed by coriander border (16). Aphid infestation on coriander was significantly higher (22) as well as maize (15). Therefore, coriander has the potential to trap the corn leaf aphids which are vectors of sugarcane mosaic virus while sorghum border has a positive effect on the yield performance of maize.

Key words: Maize, corn thrips, corn leaf aphids, Maize lethal necrosis disease, Sugarcane mosaic virus

INTRODUCTION

Maize is an important staple food crop in Kenya with per capita consumption estimated at 98 kg per annum (de Groote *et al.,* 2011). It is both a food security crop as well as a commercial crop in various parts of the country (Olwande, 2012). According to the global information network report (GIEWS, 2013), maize production in 2013 declined by more than 100,000 metric tons from the previous year, due to various constraints key among them the Maize lethal necrosis disease (MLND) (Makubi and Wangai, 2012). In Kenya the disease is as a result of co infection by two viruses, Maize chlorotic mottle virus (MCMV) and sugarcane mosaic virus (SCMV). (Wangai *et al.,* 2012). The effect of this disease has been devastating with high infection rates and significant damage, this seriously affects the yields leading to complete crop loss (Adams *et al.*, 2012; Wangai et *al.,* 2012). Since it was first reported in Kenya, the disease has spread in Uganda, Tanzania and Rwanda (Makumbi and Wangai, 2013, Adams *et al.,* 2014). Control of MLND poses serious difficulties due to the involvement of the two viruses. The MCMV is vectored by *Frankliniella williamsi* Hood while SCMV is vectored by *Rhopalosiphum maidis* Fitch which are challenging to manage. Intercropping has been found effective against thrips (*Frankliniella occidentalis)* (Kasina *et al.,* 2006, Nyasani *et al.,* 2012). Therefore this study focused on two aspects of companion crops tested as border and intercrops and their potential to prevent transmission of related viruses to the maize crop.

MATERIALS AND METHODS

Studies were conducted at farmer fields in Bomet East Sub County in Bomet County, Kenya. The trial consisted of plots measuring 7.5 m x 5.25 m arranged in a randomized complete block design with four replications. This was done in two seasons (December, 2014 to April 2015 and April 2015 to September 2015). Two factors were tested: Intercropping and Border cropping by use of the following treatments: Elephant grass (*Pennnisetum purpurerum*), sorghum (*Sorghum vulgare*), Coriander (*corriandium sativum*) and Pearl millet (*Pennisetum glaucum*) . Olerai maize *Zea mays*, variety was used as the control and main crop. Border crops and the outer lines of the intercrop were planted 2 weeks earlier while the inner rows of intercrops were planted at same time with maize. Maize lethal necrosis disease severity and incidence was carried on two rows per plot. Severity of the MLND was taken based on the scale by (Kinyua *et al.,* 2015). At harvest, 10 maize cobs were randomly picked in every plot on two inner rows. The cobs were weighed, shelled and seeds counted and weighed. The fresh and dry weight of the kernels was also taken.

DATA ANALYSES

Data were analysed using Gen Stat 17th edition. Analysis of variance was performed at 95% level of confidence limit. Skewed data were transformed by square root or $\log_{10}$ (x +1). Post hoc analyses were carried out using the Fishers Protected Least Significance Difference Test (LSD).

RESULTS

MLN vectors infestation levels and MLND severity on maize grown under various cropping systems in Bomet County

Pooled data from both seasons showed no variance in the number of vectors and MLND severity occurring on maize grown under all the polycultures cropping systems (Fig 1). However the MLND incidence levels was least in maize surrounded by Elephant grass border while the Olerai maize as the control registered a higher MLND incidence level.

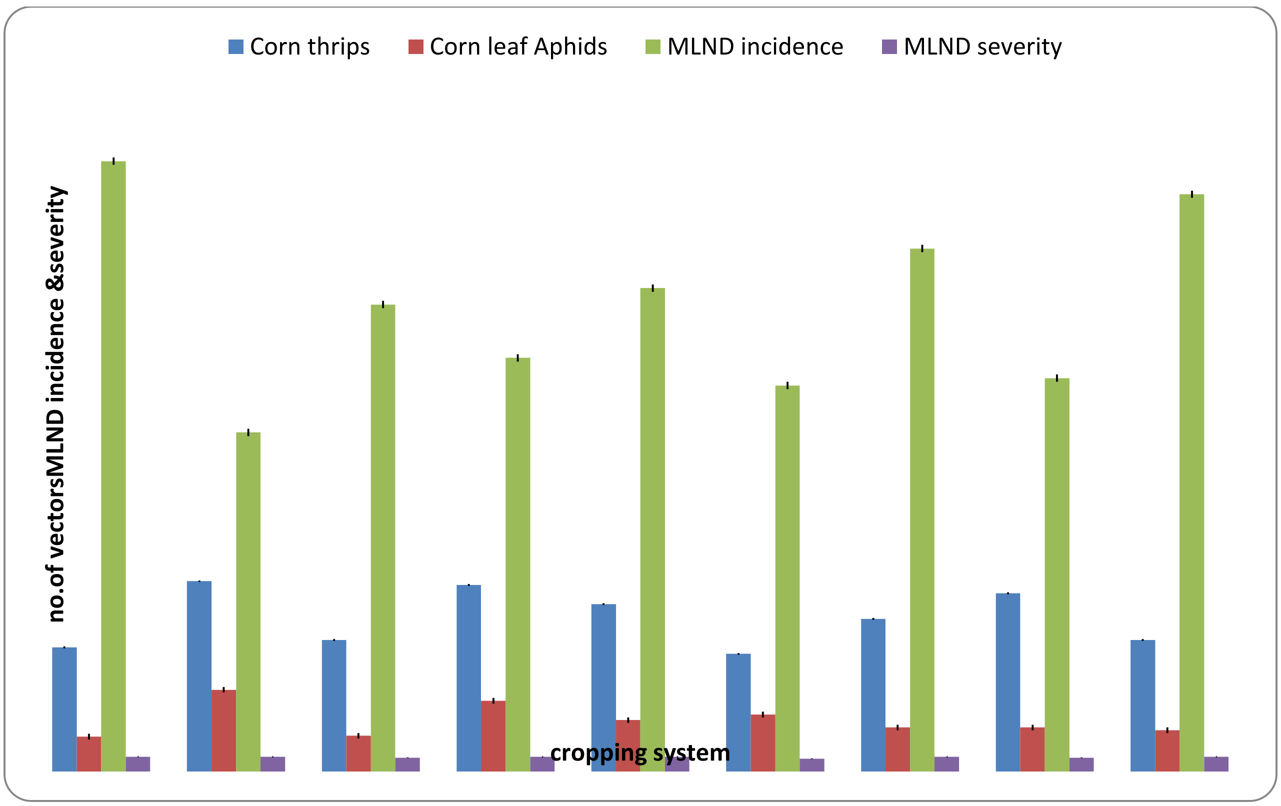

Fig. 1. Infestation levels of Corn thrips and Aphids; MLND severity and incidence on maize grown under various polycultures cropping in Bomet County Kenya

Maize surrounded by sorghum had a significantly higher % fill (79%), cob weight (126g), number of good seeds (213) and fresh weight (59g) as compared to the other cropping system. However maize monocrop registered significantly similar weight and numbers among the same variables (Table 1). Maize from coriander border had a significantly lower percentage fill (44%) as those intercropped with millet and elephant grass (6.3g and 6.0g) respectively registered the highest weight of bad seeds. Fresh weight was significantly lower from maize intercropped with sorghum (34g) as well as those from coriander border (33g) Table 1.

Table 1 Grain yield data of maize grown under various border and intercrops cropping system in Bomet County Kenya

Croping system	**% cob fill**	**cob weight**	**No. good seeds**	**No. bad seeds**	**Weight of good seeds**	**weight of bad sees**	**Fresh weight**	**Total dry weight**
Olerai Maize alone	81.56c	109.12c	239.9c	13.9	67.61d	2.561ab	70.17c	63b
Maize in by E. grass border	56b	86.27b	152b	10	46.61b	1.913a	48.52b	42a
Maize intercropped with E. grass	53.13ab	74.55a	114.9a	28.3	29.83a	6.007c	35.84ab	31a
Maize in Sorghum border	79.06c	126.35c	213.2c	17.6	56.99c	2.97abc	59.96c	53ab
Maize intercropped with sorghum	54.38ab	75.51a	110.6a	29	29.21a	5.259bc	34.47a	30a
Maize in coriander border	44.06a	70.04a	112.1a	16.7	30.83a	2.798ab	33.63a	28a
Maize intercropped with coriander	52.19ab	75.67a	125.1a	18.9	38.99ab	3.047abc	41.91ab	37a
Maize in Millet border	59.69b	74.43a	145.6a	14.2	35.51ab	2.459ab	38.7ab	34a
Maize intercropped with millet	57.5b	72.64a	116.2a	30.7	32.93a	6.261c	39.17ab	34a
P value	<.001	<.001	<.001	0.12	<.001	0.02	<.001	<.001
se	0.12	0.12	0.16		0.13	0.05	0.14	0.6

* Means within column followed by the same letter are not significantly different (*P* = 0.05).

Infestation of vectors of MLN viruses on companion crops grown under various polycultures cropping systems in Bomet County

Corn thrips infestation significantly varied among all the companion crops. Infestation of thrips on Olerai maize treatments was significantly higher (46) than the entire companion crops (Table 2). This was followed by coriander border and coriander intercrop that had a mean infestation of 16.3 and 12.9. Corn leaf aphids' infestation was significantly higher on coriander that was planted as an intercrop and a border crop of maize (Table 2). This did not vary significantly with the corn leaf aphid infestation on maize 15.4.

Table 2 vectors of MLN viruses on companion crops grown under various Cropping systems in Bomet County

Treatment	Corn thrips	Corn Aphids
maize	46±0.5d	15.4±0.6 bc
Elephant grass border	2.6±0.5a	5.1±0.6a
Elephant grass intercrop	2.9±0.5a	5.5±0.6a
Sorghum border	2.5±0.5a	6.3±0.6a
Sorghum intercrop	6.2±0.5ab	8.2±0.6ab
coriander border	16.3±0.5c	22.7±0.6c
coriander intercrop	12.9±0.5bc	22.2±0.6c
millet border	3.9±0.5a	8.7±0.6ab
millet intercrop	4.0±0.5a	7.4±0.6a
p value	≥ 0.001	0.04

* Means within column followed by the same letter are not significantly different (P = 0.05).

DISCUSSION

Both corn thrips and corn leaf aphids preferred maize as their main host when grown together with other companion crops. Therefore the different cropping system had no effect on infestation levels of thrips and aphids on maize. This could be attributed to the fact that corn leaf aphids are polyphagous in nature and this enables them to colonise maize in all treatments in every cropping system without discrimination (Potting *et al.* 2007). However, it is also clearly noted that a significant number of both corn thrips and corn leaf aphids found their habitat on coriander. Results show coriander harbouring the vectors more than the other companion crops (millet, sorghum and elephant grass). This could be advantageous to maize as the viral transmission process is interfered with. Since the companion crops were planted two weeks earlier than the target maize crop, the thrips and aphids are likely to inhabit the coriander, feed on it and in the process reduce the innoculum or lose it before they invade the maize. The transmitted virus subsequently does not affect the yield as in the case of the other yield from other cropping systems. The same trend is seen on maize surrounded by elephant grass border. Elephant grass is likely to posses chemical cues that not only repel the vectors but also reduce the virulence nature of the virus. Khan *et al.,* 2004 and Cook *et al.,* 2007 had similar results when Elephant grass successfully controlled Chilo partellus through push and pull mechanism. The infestation levels of the corn leaf aphids on coriander were significantly similar to the one on maize. It is also key to note that lack of a significance variance in the infestation levels of aphids on both coriander and the maize varieties could be exploited in the control of the maize lethal necrosis disease. In the presence of both coriander and maize, aphids have a similar probability of feeding on either crop. This may greatly reduce the virulence nature of sugarcane mosaic virus and reduce its interaction chances with the MCMV virus. Eventually, MLND levels may greatly reduce in maize planted as a polycultures even though the number of vectors remains the same. Since aphids transmits SCMV non-persistently (Gwendolyne *et al.,* 1996), it is possible to disrupt virus transmission to maize, if these aphids land on the companion crops and feed before infesting maize. This might have been the case in explaining the absence of SCMV in maize grown with coriander.

CONCLUSION

Coriander may turn out to be a good trap crop for the *F. williamsi* and Aphids. However more tests should be carried out to monitor the population build-up of the thrips throughout the growing season and relate it with the MLND manifestation in maize crops. Sorghum intercrop has more potential in as a trap crop for *F. williamsi* while millet, Napier and sorghum border has more potential as repel companion crops.

RECOMMENDATIONS

Studies are required to determine whether coriander is a host to Corn Thrips or a dead end trap crop that only offers oviposition sites but may not be able to support the development of the pest. There is need therefore to carry out more studies on other possible trap crops and stabilising the cropping systems so that a clear definite ratio can be used.

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5.Parallel Session 4 : Soil health management, input access and conservation issues

5.1 Time preference and resource use behavior by wetland users: The case of ewaso narok wetland, Kenya

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ABSTRACT
This paper assessed impacts of individual rate of time preference (IRTP) on resource use behavior of wetland users in Ewaso Narok Wetland, Kenya. The impact of IRTP on the resource use behavior was tested using the seemingly unrelated regression (SUR) model. Analysis showed that long distance from a homestead to piped water resulted in a higher IRTP. Further results showed that individuals with a higher rate of time preference used the wetland resources intensively. Secure land tenure of wetland users in the upland parcels reduced the intensity of resource use. Generally results suggest that policies should be formulated to facilitate infrastructural development like installation of alternative sources of resources like water. Title deeds should be provided for users in the upland parcels of land. Land area under crop should be minimized and number of livestock allowed in the wetland controlled. This will promote sustainable management of the wetland.
Keywords: Sustainable management; wetland resources; Land tenure; Ewaso Narok

INTRODUCTION
Wetlands have both ecological and socio-economic values such as livelihood promotion, habitats for flora and fauna, flood regulation and water filtration, (Mitchell, 2013). There are also activities which they provide like fish farming, forestry, wildlife conservancies, pastoralism and crop farming (MEMR, 2012; Thenya *et al.,* 2011). Although the wetlands have a lot of merits there are major challenges facing wetlands in sub-Saharan Africa which include climate change, population pressure, siltation and pollution (Mitchell, 2013; Nonga *et al.,* 2010; Kafle *et al.*, 2008). Kenya is not an exception, for example the Ewaso Narok wetland supports many human activities (Thenya, 2001) but it is over grazed and

intensively cultivated with over 80% of the wetland having human activities in it leading to biodiversity loss(Thenya, *et al.*, 2011; Behn, *et al*., 2013).

Biodiversity loss is brought about by the change of human behavior in the use of resources (Milner-Gulland, 2012). Human behavior can be defined as practices or observable actions performed by an individual in achieving his/her objectives (Viet gung *et al.,* 2007). There is need for a sustainable management of the wetland in order to reduce the impact of the human activities on the scarce resources. The sustainable management of natural resources is influenced by both internal and external factors such as socio-economic, individual rate of time preference and policy factors (Sullivan, 2011; Mulligan, 2007; Godoy, *et al.,* 2001).

Time preference is the tendency of a user to consider current consumption over future consumption. Rate of time preference (discount rate) induces a user to delay consumption and it refers to an amount of money which will compensate a user to forgo the current consumption (Frederick.*et al.,* 2002; Gunatilake *et al.,* 2009). A high rate of individual time preference means harvesting more of the resources in the present as opposed to the future (Gunatilake *et al*., 2009 and Di Falco, 2013).

Resource use behavior refers to the economic activities undertaken by users in and around the wetland using the available resources to meet their objectives (Viet gung *et al.,* 2007). The wetland users utilize the scarce resources in order to maximize current benefits with little known of their concern for the future generation. Understanding the impact of IRTP on resource use and its determinants will help in the sustainable management of the wetland. This will promote environmental sustainability and optimize social welfare for both the current and future generations.

METHODOLOGY

Research Design

This paper was based on a cross sectional survey in which primary data was collected from wetland users of Ewaso Narok Wetland using semi structured interview schedules. A list of the total population of 6000 registered wetland users was obtained from the Water Resource Users Associations (WRUA) and village elders. Stratified random sampling was used to sample the villages of interest. The respondents per household were drawn from the villages proportional to size using the simple random sampling. A sample size of 300 respondents was distributed across the three categories of users as follows: small scale farmers, commercial farmers and pastoralist were 106, 95, and 99 respectively.

Estimation of individual rate of time preference

This involved a set of 10 offers which had two options for the respondent to choice as shown in Table 1. The first set of option had a constant value of KES 1000 which was assumed to be received after one month (present market value) and the second option had an increment of KES 150 on top of the present value for each of the 10 offers and it was assumed to be received after six months (future value offered) (Teh, *et al.,* 2014). The respondent were to choose what they preferred from each of the offers, for example, a respondent would prefer the first option of KES 1000 up to the 4th offer and switches to a value of KES 1750 at the 5th offer. In that case the IRTP of that respondent would be calculated using the 4th value as the present offer and the 5th value as the future offer. The IRTP was determined by the point at which they switched from choosing the immediate to future payment. This estimation is on experimental approach (choice task) known as the Multiple Price List m(Teh, *et al*., 2014; Andreoni and Sprenger, 2012; Harrison, *et al*., 2002).

Another approach used in this paper was the matching task in which the respondent is given the initial offer and is required to indicate the value they would prefer given the time period (Frederick *et al*., 2002). This was in a case where the respondent persists on the smaller sooner reward up to the 10th offer. The two values (present and future) and the difference in the two times period of five months was used on the hyperbolic model in equation 1, to obtain the individual rate of time preference for each respondent (Hardisty *et al.,* 2013; Andersen *et al*., 2008; Frederick *et al.,* 2002).

$$r = \frac{\left[{}^{Fut}\!/_{\mathrm{Pre}}\right] - 1}{T} \quad \ldots\ldots 1$$

Where r is the IRTP; Fut is the future offer; Pre is the present offer and T is the difference in two time periods.

The calculation of the individual rate of time preference was the first step in the determination of its impact on the resource use behavior. Table 1 presents the IRTP associated with different offers. The annual interest rate (AR) and the annual effective interest rate (AER) were calculated using the hyperbolic model formula and the effective annual interest rate formula on equations 1 and 2 respectively. The effective annual rate accounts for the effect of compounding.

$$AER = (1 + \tfrac{i}{n})^n - 1 \quad \ldots\ldots 2$$

Where AER is the annual effective interest rate; i is the stated annual interest rate and n is the number of compounding periods.

Individual rate of time preference was used in the first regression as the dependent variable. Table 2 shows the variables used in the IRTP model. Equation 3 was used to in the estimation of individual rate of time preference.

$$Y = \beta o + \sum_{i=1}^{n} \beta i X i + \varepsilon \quad \ldots\ldots 3$$

Where, Y is the individual rate of time preference estimated in the previous equation, β_0 is the intercept, β_i are the coefficients to be estimated, X_I represents explanatory variables and ε is error term.

To assess the determinants of resource use behavior

The IRTP was estimated and used as an explanatory variable in the second estimation of determinants of resource use behavior. Land use intensity (LUI) index was used as an indicator of the resource use behavior. The land use intensity was a composite index calculated using six variables namely; capital inputs (Ksh/ha), labour input (man days/ha), land area under crop (ha), quantity of harvest (Kg/ha), rate of organic and inorganic fertilizer application (Kg/ha). These variables were subjected to dimension reduction through the Principle Component Analysis (PCA) approach

The PCA was set such that the eigenvalue of one was used meaning each observed variable contributes one unit of variance to the total variance in the data set; the factors with eigenvalue of at least one are selected. Test of appropriateness of the factor analysis was evaluated using the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO). The KMO statistic greater than or equal to 0.5 is adequate and acceptable (Field, 2009). The Bartlett's test should be significant meaning the correlation between the variables is significantly different from zero. The factors extracted explain the total variance and form LUI index which was used in the second model as the dependent variable.

The Breusch-Pagan test of independence was carried out to ascertain whether the two regression equations were to be estimated jointly or individually. The estimation of the equations would be done jointly using the SUR (Seemingly Unrelated Regression) estimator model, under the assumption that the error terms of the two equations are contemporaneously correlated. If this assumption does not hold then the regression equations are estimated individually using OLS.

SURE model was used to estimate the determinants of individual rate of time preference and resource use behavior jointly using equation 3 and 4 respectively.

$$W = \varphi_0 + \sum_{i=1}^{n} \varphi_i Z_i + \varepsilon \qquad \text{………………………………………………………………...........4}$$

Where W represented the LUI index, φ_0 is a constant φ_i are the coefficients estimated and Z_i represents the explanatory variables and ε is the error term. The variables used the land use intensity model, their description, units of measurement and expected signs are presented in Table 3.

RESULTS AND DISCUSSION

Table 4 presents descriptive statistics of variables used in the IRTP and LUI index models. The average IRTP of users in Ewaso Narok Wetland of 20.05%.which is higher than the average market interest rate in Kenya for the year 2015 was 11.50% (CBK, 2015).

Determinants of IRTP

Table 5 presents the factors which influenced the individual rate of time preference of wetland users in Ewaso Narok wetland. A one hectare increase in land area under crops in the wetland increases the IRTP by 33 percent. This means that a household which has a larger area of land on crops in the wetland utilizes more resources than a household with small land area occupancy. This contradicted the findings of (Yesuf and Bluffstone, 2008) which concluded that the land area had a negative effect to the IRTP.

Being a commercial farmer increased the individual rate of time preference by 68% above the small scale farmers. The large commercial farms were mostly located at the upland area and pumped water for irrigation from the wetland. Most of the small scale farms were located inside the wetland and used mostly bucket irrigation which is more conservative. This means that commercial farmers are the largest contributors of degradation in the Ewaso Narok Wetland.

Being a member of a group increases the IRTP by 61%. The group membership was associated with access to loans which were used for agricultural inputs and other farm activities (Mnimbo, 2013). A household member being in a group accelerates the degradation of the wetland through increased input use.

One kilometer increase in the distance of a household to piped water increases the IRTP by 3 percent *ceteris paribus.* The piped water was used as an indicator of alternative source of water. This means that the use of resources like water would reduce if alternative sources of resources are provided and this would promote sustainability of the wetland.

Determinants of land use intensity (LUI) index

PCA results showed a KMO of 0.524 and the Bartlett's test was significant at $p<0.000$ thus supporting the factorability of the correlation matrix. The factors extracted were explaining 72% of the variance. Table 6 presents the factors influencing land use intensity. IRTP had the largest magnitude in influencing the LUI; this was followed by socio-economic factors (group membership) and the policy factors (tenure security).

One unit increase in the individual rate of time preference increases the land use intensity by 1.65. Individuals with a high rate of time preference use more of the wetland resources. This is consistent with findings by Gunatilake *et al.,* (2009) and Di Falco, (2013) that high individual rate of time preference means harvesting more of the resources in the present and less conservation. This means that the IRTP should be a major consideration in the decisions of sustainable management of the Ewaso Narok Wetland.

A unit increase in TLU increases land use intensity. This implies that, households which have large herd of livestock use more pasture and water resources from the wetland than those with fewer animals. This finding is consistent with the findings of Sourya *et al.*, (2015) which found a positive effect of the number of livestock owned and wetland use. This means the large numbers of livestock which graze within the Ewaso Narok Wetland contribute to its degradation.

An increase in the family size of a wetland user increases the intensity of land use. Larger households have available labour that can be allocated to a wide range of activities including utilizing wetland resources. This was similar to the findings of Sourya *et al.,* (2015) which also found a positive effect between household size and the use of the wetland resources.

A one kilometer increase in distance from a homestead to piped water increases the land use intensity. This means provision of alternative sources of resources like piped water would promote sustainable management of the Ewaso Narok Wetland.

A household member being in a group reduced the land use intensity by 1.24. This could be due to access of loans which facilitated diversification to other activities outside the wetland use. This was consistent with the findings of Mnimbo, (2013) which concluded that group membership improved the level of income through provision of loans and encouraged diversification into businesses. Group membership enhances diversification into activities which are not dependent on the wetland resources and therefore promote sustainability.

A year increase in the level of education reduced the land use intensity. A high level of education of an individual could be associated with higher income which leads to diversification to alternative resources and hence the intensity of using the wetland resources decrease. This was consistent with the findings of Felix, (2012) which found a positive effect between education and resource use in the wetland.

Having secure land tenure decreases the intensity of land use by 0.94. The wetland users with secure land tenure were those located in the upland area and had title deeds. This means that those users with secure land tenure used the resources conservatively as opposed to users who had insecure land tenure. This means that the securing land tenure in the upland area encourage conservation of resources in the wetland.

TABLES

Table 1: Individual rate of time preference using choice and matching task methods

Offer after 1 Month	Offer after 6 Months	AR	AER	Respondents on switch point
(Constant value of KES 1000)	1150	0.36	0.39	32
	1300	0.72	0.86	15
	1450	1.08	1.4	9
	1600	1.44	2.02	14
	1750	1.8	2.71	13
	1900	2.16	3.48	13
	2050	2.52	4.33	42
	2200	2.88	5.25	29
	2350	3.24	6.26	24
	2500	3.6	7.35	4
	3000	4.8	11.5	8
	4000	7.2	22.9	1
	5000	9.6	38.1	12
	6000	12.01	57.5	7
	10000	21.6	178.7	37
	12000	26.4	266.7	2
	15000	33.6	434.7	3
	17000	38.4	571.3	1
	20000	45.6	814.4	8
	50000	117.7	5970.9	12
	60000	141.8	8869.1	3
	100000	237.9	26857.1	9

Source: Author's Survey, (2015).

Table 2: Variables used in individual rate of time preference model

Variables	*Description*	*Measurement*	*Expected sign*
Dependent variable			
IRTP	Individual rate of time preference	Percentage	
Independent variables			
Group membership	Wetland user being a member of a group	Dummy(Yes=1)	+
Commercial farmer	Wetland user being a commercial farmer	Dummy(Yes=1)	+
Pastoralist	Wetland user being a pastoralist	Dummy(Yes=1)	-
Land area on crop	Land area on crop in the wetland	Hectares	+/-
Distance piped water	Distance from a homestead to piped water	Kilometers	+
Proportion sold	Proportion of crop harvest sold	Percentage	+
Total income	Total income of the household	KES	-
Distance to wetland	Distance from a homestead to the wetland	Kilometers	-
Conflicts of users	Conflicts of wetland user on the use of resource	Dummy(Yes=1)	+

Table 3: Variables used in land use intensity model of Ewaso Narok Wetland user

Variables	*Description*	*Measurement*	*Expected sign*
Dependent variable			
LUI	Land use intensity	Index	
Independent variables			
Estimated IRTP	Estimated individual rate of time preference	Percentage	+
Land tenure	land ownership type	Dummy(secure=1)	-
Market access	Distance from a homestead to the nearest shopping center	Kilometers	+
Household size	Household size	Adult Equivalent	+
Education	Level of education of the household head	Years	-
Group membership	Household member being in a group	Dummy(Yes=1)	-/+
Wildlife danger	Danger of wildlife in wetland	Dummy(Yes=1)	-
Distance piped water	Distance from a homestead to piped water	Kilometers	+
Total income	Total household income	KES	-
TLU	Tropical livestock unit	Number	+/-
Years wetland use	Number of years of using the wetland	Years	+

Table 4: Descriptive statistics of the variables

Variable	Average	Standard deviation	Minimum	Maximum
LUI index	0	1.53	-4.97	7.87
Income (KES)	25162.42	37579.21	0	309934
Market access (Km)	7.25	7.91	0	36
Education (Years)	5.13	4.75	0	20
Landsize under crop in wetland (Ha)	0.82	0.84	0.04	7.48
Distance piped water (Km)	10.91	12.52	0	77
TLU (Number)	18.72	46.19	0	580
Years of using wetland	14.91	8.22	1	35
Household size (Adult equivalent)	4.43	1.89	0.75	10.05
IRTP (%)	20.02	47.29	0.36	239.98
Distance from homestead to piped water (Km)	10.91	12.52	0	77
Distance from homestead to wetland (Km)	1.95	1.88	0	10
Proportion of harvest sold (%)	0.44	0.23	0.04	1.11

Source: Author's Survey, (2015)

Table 5: Factors influencing individual rate of time preference of Ewaso Narok Wetland users

Independent variables	*Coefficient*	*Std error*	*P value*
Distance of household to piped water (Km)	0.03***	0.01	0.00
Distance of household to the wetland (Km)	0.14	0.10	0.13
Land area on crop in the wetland (Ha)	0.33**	0.15	0.03
Proportion of harvest sold (%)	-0.66	0.62	0.28
Total household Income per annum (KES)	-0.06	0.06	0.29
Group membership	0.61**	0.29	0.03
Commercial farmers	0.67**	0.32	0.03
Pastoralists	0.41	0.90	0.65
Conflicts among users	0.40	0.31	0.19
Intercept	-0.05	0.49	0.91

Source: Author's Survey, (2015) **, *** means significance at 5%, 1% respectively

Table 6: Determinants of land use intensity for Ewaso Narok Wetland users

Independent variables	*Coefficient*	*Std error*	*P value*
Estimated IRTP	1.65***	0.46	0.00
Household size (Adult equivalent)	0.60*	0.35	0.09
Education (Years)	-0.11**	0.05	0.03
Total household income per annum(KES)	-0.01	0.08	0.19
TLU (Number)	0.01***	0.04	0.00
Group membership	-1.24***	0.16	0.00
Danger of wildlife	0.66	0.44	0.19
Tenure security	-0.94**	0.39	0.02
Distance of household to piped water(Km)	0.05**	0.34	0.02
Years of using the wetland	0.02	0.02	0.35
Distance to the shopping centre(Km)	-0.03	0.02	0.20
Intercept	-1.69	1.51	0.27

Source: Author's Survey, (2015) *, **, *** means significance at 10%, 5% and 1% respectively.

CONCLUSION

Sustainable management of the Ewaso Narok Wetland would entail a change of human behavior in the use of resources. The human behavior is influenced by both external (policy) and internal (IRTP and socio-economic) factors. The average IRTP of users in Ewaso Narok Wetland was higher (20.05%) than the mean market interest rate in the year 2015. The IRTP had the highest magnitude and a positive effect in influencing resource use behavior. This implied that the wetland users used more of the wetland resources in the present. Therefore, the sustainability of the wetland is at stake. In order to sustainably manage the wetland alternative sources of resources like piped water should be provided near the wetland area in order to minimize the over dependence on resources. Land area under crop should be minimized per household and the intensity of grazing livestock controlled. Land tenure of the wetland users in the upland parcels should be secured to enhance sustainable use of the wetland resources.

Policy implications

Following the above conclusion therefore, this study draws the following policy implications; there should be provision of title deeds in the upland fields. The land tenure of the wetland users in the upland parcels of land should be secured; this will encourage sustainable use of resources in the wetland.

The government should enact policies that encourage infrastructural development such as installation of piped water in the upland area. This will reduce the rate of extraction of water from the wetland. Land area under crop within the wetland area should be minimized and the intensity of grazing livestock in the wetland should be controlled to facilitate sustainable management.

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5.2 The effect of invasive plant (Lantana camara) on soil chemistry at conservation area ol-donyo sabuk national park, Kenya

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ABSTRACT

Invasive species are a major ecological and management concern in natural ecosystems and pose a threat to many of Kenya's protected areas. Invasive plant species compete and hybridize with native species often to the disadvantage of the native species. Invasion of native plant habitats by invasive plants can drastically change soil chemical properties such as pH, mineral composition and mineral levels. The aim of this study was to establish whether the invasive plant *Lantana camara* L. alters the soil nutrients. Five study sites were selected by purposeful sampling. Soil samples were collected randomly from *L. camara* invaded areas and similarly from adjacent areas free from *L. camara.* The soil samples were analysed for the following: pH, potassium (K), calcium (Ca) magnesium (Mg), total nitrogen (N), phosphorous (P). All statistical analyses were done using Statistical Analytical Software (S.A.S) portable version 9.4 software to determine differences in nutrients composition in
Lantana invaded and non-invaded areas. Results of the study indicated soils from *L camara* invaded areas had an increase in pH value, phosphorous, nitrogen compared to the non-invaded areas. Most nutrient levels were found to be higher in the invaded than the invaded due to high pH. The slight pH in this case also made phosphorous to be more available to the *L. camara* invaded areas. This study therefore reveals that *Lantana camara* has effect on the soil nutrient levels leading to changes in soil chemistry of invaded areas. This is in a bid to suit its survival to the detriment of the native plants.

Key Words: Invasive species, native species, soil nutrients, habitats, *Lantana camara*.

INTRODUCTION

Invasive plant species are among the world's greatest threats to biodiversity and native species in protected areas (Lwando, 2009). Invasive species may change the community structure through competition which is categorised into two; exploitation competition whereby there is indirect interactions in the use of resource and interference competition (Callaway and Ridenour, 2004). Once invasive plants become established, they change the soil nutrients and shift nutrient cycling in an ecosystem. Soil is important to plants because it is a source of nutrients that are utilised by plants for various physiological processes. Other than nutrients soil also has microorganisms, some have a relationship with plants. Both native and invasive plants form some relationships with bacteria and fungi in the soil that facilitate the extraction and conversion of elements to biologically usable forms (Batten *et al*., 2006). Some convert atmospheric nitrogen into usable forms that are then exchanged for carbon from the plant. Nitrogen in form of nitrates and nitrites are frequently limiting in soils, yet many invaded ecosystems have shown to have more carbon and nitrogen in plant tissues and soils compared with systems dominated by native plants (Mack *et al*., 2000).

Invasive plant species pose a serious threat to biodiversity and are now considered second to habitat destruction in driving global biodiversity loss (Batten *et al*., 2006). Invasive plant species have many impacts on plant communities through their direct and indirect effects on soil chemistry (Ehrenfeld, 2003) as plant community composition changes, preferred wildlife habitats are destroyed hence destabilizing such protected areas.

Lantana camara L. is one of the most invasive plants and has been ranked as the highest impacting invasive species (Batianoff and Butler, 2003). It is top among the world's 100 worst invasive alien species (GISP, 2003), because it possess great potential to escape cultivation and have deleterious effect on species richness (Islam, 2001). *Lantana camara* L. is a major weed in over 60 countries and is one of the 10 worst weeds worldwide (Sharma *et al.,* 2005). In Australia, *Lantana* is a weed which has evoked a national outcry, having invaded at least 4 million hectares of predominantly coastal and sub-coastal ranges of eastern Australia (Parsons and Cuthbert, 2001). *Lantana camara* has invaded disturbed forest land and neglected pasture in much of its naturalized range. *Lantana* also now seen invading native vegetation in woodlands and savannas notably in protected areas (Englberger, 2009). In some areas, competition by the shrub results in a reduction of biodiversity (Kumar and Rohatgi, 1999). Despite the establishment of a number of natural enemies of *Lantana* in exotic populations, control of its populations has been usually limited or failed (Day *et al*., 2003). In thick stands, the shrub increases costs in forest management by inhibiting access in stands for thinning and felling, competes through rapid reproduction and increases fire hazards (Graaff,1986).

The impact of invasive plant species in protected areas, mostly National Parks and reserves in Kenya is currently poorly understood and the magnitude of the problem is not well appreciated (Simba *et al*., 2013). Studies show that Kenya has been invaded by 34 different species; eleven arthropods, ten micro-organisms, nine plant species and four vertebrates (Farrell *et al*., 1995; Lyons, 1999). Some of these invasions have yielded significant consequences on socio-economic status. Notable examples of invasive plants include the water hyacinth (*Eichhornia crassipes* Mart) (Hill *et al*., 1999) in Lake victoria, the water fern *(Salvinia molesta* D.S Mitch.) in Lake Naivasha, Mathenge (*Prosopis juliflora* S.W) in the Rift Valley (Baringo); Tickberry (*Lantana camara* L) in Nairobi National Park; Jimsonweed (*Datura stramoniun* L) grows more in disturbed habitats example construction sites; Long spine cactus (*Opuntia exaltata* L); Sweet prickly pear (*Opuntia ficus indica* L); Drooping prickly pear (*Opuntia vulgaris* Miller) *Opuntia* species mostly in drier areas as hedges and boundaries (Naivasha); Wild garlic (*Allium vineale* L) Mt Elgon; Mexican marigold *(Tagetes minuta* L.) Morning glory (*Ipomoea indica* (L) Roth) in Kiambu County and Eucalyptus (*Eucalyptus globules* Labill) Kenyan riparian zones (Kedera, 2005). In the present study soil samples were analysed to determine soil nutrient composition in the areas invaded by *Lantana camara* and those that are not invaded. It is hypothesized that *Lantana camara* has no effect on soil nutrient composition.

MATERIALS AND METHOD

The study was carried out in Ol-Donyo Sabuk National Park. The Park is located about 85km North-East of Nairobi in Machakos County. It lies between latitudes $1^{0}5'$ and $1^{0}10'$S, longitudes $37^{0}10'$ and $37^{0}20'$E and altitude 2145 metres above sea level at the peak of the hill. The regime is bimodal with rains occurring mostly from March to May and October to December with peaks in April and November. The maximum annual mean temperature is between 22^{0}C-26^{0}C and minimum annual mean is 10^{0}C-14^{0}C. January-March is hot and dry, April-June is hot and wet, July-October is very warm and dry, November - December is warm and wet (KWS, 1999). The soils are varied due to geological formation; shallow and stony with rocky outcrops which have been subjected to geological and recent accelerated erosion losing their original characteristics (KWS, 1999). Communities around the Park utilise the Park resources for basic needs like firewood, grass, meat from wildlife, medicinal plants, honey and pollinator services; in some cases illegal charcoal burning and livestock grazing. Encroachment and edge effects resulting from increased population and associated disturbances are some of the activities are some of the factors that have contributed to the introduction of invasive plant species into the National Park. The most common invasive plant species found at Ol-Donyo National Park are: *Lantana camara, Datura stramonium* L, *Solanum incanum* L, *Dovyalis caffra* Warb, *Ricinus communis* L, *Tagetes minuta* L, *Caesalpinia decapelata* (Roth) Alston (Faden, 1974).

The soil samples were taken in the months of November to December for the wet season sampling while the dry season sampling was carried out between January and March. By purposeful sampling, 5 blocks were selected; this was done to achieve a clear representation of the sample size of the whole Park. In each block, 2 quadrants (10mx10m) at interval of more than 100m were established randomly using tape measure and wooden pegs. One quadrant invaded by *L. camara* and the other with native plant species (non-invaded) and soil samples were then collected using a soil auger. The soil samples from the sampling points were composited to one sample and desired amount of the collected soil samples was scooped and packed in airtight polythene bags. They were then clearly labelled and taken to the laboratory for analysis.

Soil pH value was determined using a pH meter – Geo-technical Engineering Bureau method (State of New York Department, 2007). The soil samples were separated on the ¼ inch (6.3 mm) sieve. 30 g of soil was weighed and placed into the glass beaker, 30g of distilled water was added to the soil sample and stirred to obtain soil slurry and then covered with watch glass. The samples were left to stand for a minimum of one hour. This is to allow the pH of the soil slurry to stabilize. The temperature of the soil samples was measured and the temperature controller of the pH meter was adjusted to that of the soil sample temperature. The pH meter was standardized by means of the standard solutions. The soil samples were stirred well with a glass rod then the electrodes were placed into the soil slurry solution and the beaker turned gently to make good contact between the solution and the electrodes. The pH value was read and recorded.

Phosphorous, potassium, calcium and magnesium nutrient elements (P, K, Ca, Mg) were analysed using the Mehlich Double Acid Method (Mehlich, 1953). The soil samples were oven dried to remove moisture. For each nutrient analysed, a soil sample was extracted in the ratio of 1:5 (weight/volume) and introduced in a mixture of 0.1M dilute hydrochloric acid and 0.025M dilute sulphuric acid. Ca, and K elements were determined using a flame photometric method (Toth and Prince, 1949) while P and Mg were determined using a Calorimeter.

Data Analyses

The soil samples were analysed in three replicates and averages obtained for the following nutrients and parameters: soil pH, potassium (K), calcium (Ca) magnesium (Mg), total nitrogen (N), phosphorous (P). All statistical analyses were done using Statistical Analytical Software (S.A.S) portable version 9.4 software. Differences among the treatment means were assessed by ANOVA. Significant differences among the means were found through Tukey's Honestly Significant Difference Test at 95% means was used to separate the means .The data was presented in descriptive tables and graphs.

RESULTS

There was significant difference (P-value <0.0001) between the *Lantana* invaded and non-invaded areas (Figure i) in pH. The *Lantana* invaded areas had high pH value (6.68) compared to the non-invaded that had pH value (6.30).

Total nitrogen concentration varied significantly (P-value 0.0271) between the *Lantana* invaded and non-invaded areas. The *Lantana* invaded areas had higher mean (0.26 %) in total nitrogen concentration compared to the non-invaded (0.18%).

Phosphorous concentration varied significantly (P-value <0.0001) in the *Lantana* invaded and non-invaded areas. The *Lantana* invaded and non-invaded areas had the same mean (20.93me%) in phosphorous concentration.

There was significant difference (P-value = 0.0037) between the *Lantana* invaded and non-invaded areas. The areas not invaded by *L. camara* had higher mean

(1.89me%) in potassium concentration compared to the invaded areas that had lower mean (1.79me%).

The concentration of calcium did not vary significantly (P-value = 0.2054) between the *L. camara* invaded and non- invaded areas. There was significant difference (P-value <0.0001) between the *Lantana* invaded and non-invaded areas in magnesium concentration. The non-invaded areas had higher mean of (3.04me%) in magnesium concentration compared to the non-invaded areas that was lower mean (2.71me%).

Comparison of nutrients levels in invaded and non-invaded areas

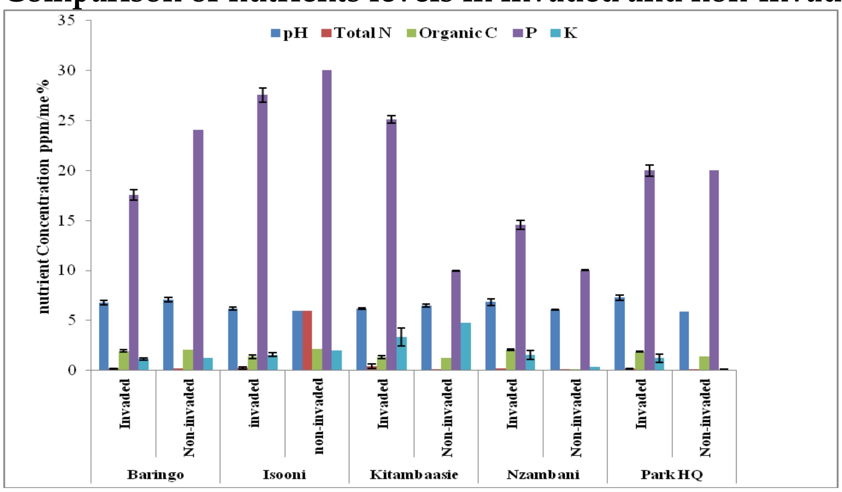

Figure i:

In summary comparison of nutrients between the *Lantana* invaded and non-invaded areas showed that *Lantana* invaded areas had higher levels of pH, total nitrogen, phosphorous, magnesium and potassium (Figure i).

DISCUSSION AND CONCLUSION

From the results obtained in this study invasive plant species, *Lantana camara* changes physical and chemical attributes of soils including pH and soil nutrients. The soil pH and most of nutrients varied significantly (P-value <0.05) among the study sites except for Calcium (P-value >0.05). Soil pH value was higher in the soils invaded by *L. camara* during this study. This is consistent with the results reported by Osunkonya *et al*. (2010), following *L. camara* invasion in South Eastern Queensland, Australia, Fan *et al.* (2010) due to *Lantana* invasion in China and Sharma and Raghubanshi (2009) following *Lantana* invasion in India.

There was significant difference (P-value <0.05) in total nitrogen and the concentration was higher in the *Lantana* invaded areas than in non-invaded areas. This is in agreement with (Rout and Callaway, 2009) who have reported that many plant invasions, despite dramatic decreases in local diversity, appear to increase local soil nitrogen pools and total ecosystem nitrogen stocks. High nitrogen availability favours invasive plants, and low nitrogen availability favours native plants (Laungani and Knops, 2009).

These results are also in agreement with Simba *et al*. (2013) findings on *L. camara* at Nairobi National Park who reported that *Lantana* leaf litter on decomposition release cations into the soil within its root rhizosphere and subsequently increased the concentrations of magnesium, calcium and potassium. The accumulated organic matter also mulches the soil surface under the invasive plant species hence inhibiting leaching of nutrients from the soil surface (Simba *et al*., 2013). According to the findings of this study there was high concentrations of potassium were found in *Lantana* invaded areas, this concur with Basumatary and Bordolo (1992) who found out that a layer of organic matter increases the retention of potassium in the soil. In the current study high soil pH was found in the *Lantana* invaded areas and according to Simba *et al*. (2013) high soil pH accelerates litter decomposition. The results are also in agreement with Osunkonya *et al*. (2010) study on *L. camara* who reported that soil within *Lantana* patches had greater air dried water content, higher organic and total organic carbon, higher exchangeable calcium, and higher pH than soils from adjacent vegetation lacking the weed. More research has to be done to investigate if *L. camara* leaf litter causes changes in the composition of the soil in the Park.

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5.3 Determinants of use of integrated soil fertility management strategies and phosphorus management for maize production intensification in Runyenjes sub-County, Kenya.

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ABSTRACT
Poor soils have negatively impacted food production. Consequently, researchers have designed strategies that can reverse the poor soils trend and increase food production. However, the adoption breakthroughs of such solutions is wanting. Therefore, the objectives of this study were to (i) determine how household socio-economic and demographic factors influence use of integrated soil fertility management strategies for maize production, (ii) determine how management practices of farmers affect available phosphorus levels in the soil. The study considered three ISFM strategies; use of inorganic fertilizer, use of organic manure and combined use of inorganic and organic fertilizer with improved seeds. Data collected included demographic and socio-economic characteristics of small-holder farmers, type and amount of fertilizers used on maize, soil samples were also collected. Descriptive statistics, ordinary least squares regression and binary logistic regression models in SPSS version 20 were employed during analysis. Results showed household size (positive), size of land under maize (negative), off-farm income (positive) and maize yield (positive) as significant (p<0.05) predictors of the amounts of phosphorus fertilizer used for maize production. Household head occupation (negative), size of land under

maize (positive), off-farm income (positive), maize yield (positive) and training (positive) were the significant ($p<0.05$) factors influencing use of animal manure for maize production. Size of land under maize (negative), household labor (positive), off-farm income (negative) and tropical livestock unit (positive) were significant ($p<0.05$) predictors of combined use of inorganic and organic fertilizer with improved seeds. Soil analysis results showed that the study area had moderately acidic soils (mean=5.60) with moderate levels of available P (mean=39.75ppm). Amount of NPK (positive), intercropping of maize with a legume (positive) and liming of soil (positive) were found to be possible predictors of available P levels on maize farms at ($p<0.05$). Thus, these factors must be considered during the coining of yield increasing technologies.
Key words: Soil fertility, inorganic fertilizer, animal manure, improved seeds, phosphorus management

INTRODUCTION

Soil capital is a major resource that smallholder farming households rely on for food and income resources (Marenya and Barrett, 2007). In Sub-Saharan Africa (SSA), smallholder farmers have been experiencing dwindling agricultural produce that is attributable to soil fertility depletion, which is resulting to food insecurity (Ngetich *et al*., 2012; Adekele *et al*., 2010). Maize crop being one of the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America (Iken and Amusa, 2004); its production intensification must be emphasized to ensure food security. Maize yields on most smallholder farms in SSA has remained less than one tonne per hectare threatening households' food security for over 70% of the rural populations as they primarily draw their livelihoods from agriculture (Muzari *et al*., 2012; Tauro *et al*., 2011).

Integrated soil fertility management (ISFM) has been proven to reverse nutrient depleted soils to productive ones (Mucheru-Muna *et al*., 2014; Akinola *et al*., 2010; Vanlauwe *et al*., 2010), but the adoption of such technologies is still wanting. The overall goal of ISFM is to maximize the interactions that result from the potent combination of fertilizers, organic inputs, improved germplasm, and farmer knowledge (Vanlauwe *et al*., 2015). The ultimate outcome is improved productivity through wiser farm investments and field practices. It has also been proven that effective use of organic soil amendment methods in combination with inorganic fertilizer could help reverse the nutrient depletion trend (Mucheru-Muna *et al.,* 2014; Akinola *et al*., 2010). The concern thus remains on why farmers are not adopting these strategies fully.

Developing soil fertility management options for increasing productivity of staple food crops is a challenge in most parts of Sub-Saharan Africa, where soils are constrained by nitrogen (N) and phosphorus (P) deficiencies (Tauro *et al*., 2011). Phosphorus is one of the most important fertility components for maize as it is the second largest consumed nutrient in global agriculture production, being surpassed only by nitrogen (Batten, 1992). Where sometimes nitrogen can be fixed into the soil by rotations of maize with beans having nitrogen fixing nodules (Ngetich *et al*., 2012), phosphorus deficiencies have to be supplemented from external inputs. Consequently, most of the N required for agricultural productivity in the continent comes largely from a judicious management of biological N fixation mostly through cereal-legume intercropping systems (Mucheru-Muna *et al*., 2010; Giller, 2001; Jerenyama *et al*., 2000; Giller *et al*., 1994) but P deficiencies have to be supplemented from external outputs. On another note, phosphorus has one of the lowest use efficiency among the plant macronutrients and a 50% yield reduction has been observed from P deficient conditions relative to the well fertilized production fields (Fageria and Baligar, 1997). Phosphorus availability is affected by farmer management practices and this must be explored.

METHODOLOGY

Description of the study site

The study was carried out in Runyenjes sub-County in Embu County of Kenya. Runyenjes sub-County lies in the Upper Midland 2 and 3 (UM 2, UM3) at an altitude of approximately 1,200-2,070 meters above sea level. It covers 149 km^2, out of which 96.26 km^2 is arable land. The estimated population is 64,111 (GoK, 2010) with a population density of 561 persons per Km^{-2}. The average farmholding is 0.4-0.8 ha. The annual mean temperature ranges from 12 °C to 27 °C. The average annual rainfall is 1495 mm and the range is between 1,000-2,000 mm. Rainfall distribution is bimodal with long rains from mid-March to May and short rains from October to December. The soils are well drained and mostly Nitisols.

Sampling design and sample size

The study design was a survey. Both quantitative and qualitative research frameworks were used. The study employed two sources of data. Primary sources**;** that included interviews, direct observation and photography. Secondary sources**;** included information from published work, relevant books, relevant seminars and conference meetings reports, and mostly the internet. Review of secondary data enabled the construction and adjustment of the questionnaire accordingly.

Runyenjes sub-County was targeted for this study; Runyenjes was purposefully selected as it is characterized by smallholder farmers who grow both subsistence and cash crops that include maize. Stratified random sampling was used as the sub-County is divided into villages with households. A total of 100 households was obtained using sample size calculator software (CRS, 2007) at a confidence level of 95% and confidence interval of 9.8%.

$S = Z^2 * (p) * (1-p) / c^2$
(1)
Where: S=Sample size, Z=Z value (e.g. 1.96 for 95% confidence level), p=percentage of picking a choice, expressed as decimal (0.5), c=confidence interval, expressed as decimal (0.098)

Soil sampling and analysis
Soil samples were collected from fields of each of the 100 farmers interviewed. The soil sample was collected at 20 cm depth. Three (3) soil cores were collected according to variability and size of land and then composited to produce one sample for analysis per farm. All samples were oven-dried at 40^0 C prior analysis. Available nutrient elements (P, K, Na, Ca, Mg and Mn) were analysed using Mehlich Double Acid method (Mehlich, 1984). Calorimetric method was used to determine organic carbon similar to Mairura et al. (2007). Total nitrogen was determined using Kjeldahl Digestion method (Anderson and Ingram, 1993). Soil pH was determined in a 1:1 (w/v) soil – water suspension with pH meter. Available trace elements (Fe, Zn and Cu) were extracted with 0.1 M HCl then determined with Atomic Absorption Spectrophotometer.

Data Analysis
Data was analysed using both descriptive and inferential statistics using SPSS version 20. Ordinary least squares regression was used to determine the factors affecting the use of inorganic and organic fertilizer for maize production. Ordinary least squares regression was also used to determine the management factors of farmers affecting amounts of available P on maize farms in Runyenjes sub-County. Binary logistic regression was used to determine the factors affecting combined used of inorganic and organic fertilizer with improved seeds for maize production in the sub-County. All these analysis was done using SPSS version.

RESULTS AND DISCUSSIONS

Use of inorganic fertilizer for maize production intensification by farmers in Runyenjes sub-County

Results indicated that only 18% of the farmers interviewed in Runyenjes sub-County used sole fertilizer in maize production (Table I). Only two percent of the farmers interviewed applied sole manure to their maize crop, while 4% of the farmers had no fertilizer or manure input on their maize farms (Table I). Results showed 78% of the farmers as users of animal manure and out of these 76% combined fertilizer and animal manure in maize production (Table I). Results also indicated that there were 70% users of DAP fertilizer, 73% users of NPK and 38% users of CAN. The average rate of DAP fertilizer application in maize fields was 63.84 kg/ha (Table I). The average rate of NPK 23:23:0 application in the study area was 87.73 kg/ha, while that of CAN was 35.77 kg/ha (Table I). A negative linear correlation was observed between size of land under maize and rate of DAP use, Pearson correlation = -0.534, p = 0.0001 (2-sided). This implies that as the size of land increases the rate of use of DAP decreases. Larger piece of land demands more fertilizer resources that a small holder farmer might not have access to. A negative linear correlation was also observed between size of land under maize and rate of NPK 23:23:0 use, Pearson correlation = -0.581, p = 0.0001 (2-sided).

Larger holdings are likely to have lower rate of NPK use as larger farm holdings demand more fertilizer resources. This was also expounded by Zingore *et al*. (2007), who mentioned that farmers with little inputs usually apply them on farms where the main crop is grown; and these farms are usually near the homesteads. This means that farms further from the homes are usually under-fertilized. In recent years, there has been an increase in the use of high nutrient fertilizers, mainly for economic reasons (Ademba *et al*., 2015). This might be responsible for the increasing rates of fertilizer use in rural areas, although not up to recommended levels. A study by Rware *et al*. (2014), reported that fertilizer recommendations were still not followed in Kenya, although some increase in fertilizer use is notable.

Socio-demographic factors affecting amounts of phosphorus fertilizer used by farmers in Runyenjes sub-County

Three variables positively influenced use of phosphorus fertilizer by farmers in maize production (Table II), these were household size, off farm income and maize yield. Size of land under maize was negatively associated with phosphorus fertilizer use. This implies that as the household size and off-farm income of the household increased the higher the likelihood of using phosphorus fertilizer. Similarly as the maize yields obtained increased, the farmer is more likely to use phosphorus fertilizer. On the other hand, as size of land under maize increased the farmer was less likely to use phosphorus fertilizer.

Results also indicated that a large household is more likely to use phosphorus fertilizer for maize production (Table II). Large households always demand more food resources and thus the need to increase maize production. Furthermore family labor associated with large household is cheap and readily available and thus increases tendency to use new technologies. As Marenya and Barret (2007) explain, family labor assumes great importance given that low incomes associated with rural small holder farmers constrain financial liquidity for hiring wage laborers. Mugwe *et al*. (2009a) and Mugwe *et al*. (2008) confirm the positive association of household labour and adoption of soil improving technologies.

Maize yield was found to be positively associated with the use of phosphorus fertilizer in maize production (Table II). This reveals that households with increased yields attributable to inorganic fertilizer use were more likely to use phosphorus fertilizer in maize production. Mucheru-Muna *et al*. (2014) and Mucheru-Muna *et al*. (2007) concluded that inorganic fertilizer was a very important input in the increase of maize yields in the Central Highlands of Kenya. With the poor fertility of soils in SSA, farmers are increasingly being aware of the fact that inorganic fertilizer is playing a major role in the increase of crop yields. Mapila *et al*. (2012) and Morris *et al*. (2007) explained that a household's potential profitability from using fertilizer is determined by the responsiveness of the crop to which fertilizer is applied.

The positive association of off-farm income with increased use of phosphorus fertilizers (Table II) in maize production is attributed to the fact that inorganic fertilizer purchase requires some monetary allocation. Having an off-farm income could enable a farmer to purchase fertilizer. Muzari *et al*. (2012) confirms this in that higher levels of income from other sources will lead to higher rates of adoption of yield-raising technology. Similarly, Marenya and Barret (2007) states that non-farm income from informal and formal non-agricultural employment proved quite important in fostering adoption of the integrated soil fertility management technologies in western Kenya.

Negative association of size of land under maize and phosphorus fertilizer use (Table II) indicated that a farmer with a larger area under maize was less likely to use phosphorus fertilizer for maize production. Large farms demand more in terms of inputs and resources, and this might be a challenge to rural farmers who in most cases are poor. This agreed with Marenya and Barret (2007) who found that size of land was a significant factor affecting fertilizer use although estimated marginal effect of farm size was largest for inorganic fertilizer. Wiredu *et al*. (2014) measured the intensity of ISFM adoption by the proportion of land that was assigned to it, showing land as an important factor of adoption.

Socio-demographic factors affecting use of animal manure among farmers in Runyenjes sub-County

Regression results showed that use of animal manure for maize production was influenced by five variables; household head occupation (negative), size of maize land (positive), off farm earnings (positive), maize yield (positive) and training on animal manure (positive) (Table III).

The positive association of off-farm income and animal manure use (Table III) in maize cultivation means that a household with an off farm income in the study area is more likely to use animal manure in maize cultivation. Limited manure availability is common in sub Saharan Africa and a household with extra income probably from off farm sources is able to purchase livestock that produce animal manure. Off-farm income enables a farmer to purchase inputs (Adolwa *et al*., 2012; Akinola *et al*., 2010) including livestock which are the main source of manure (Ajayi *et al*., 2007). For example, according to Zingore *et al*. (2007), small holder farmers with limited inputs resources usually apply them to farms near the homesteads only and neglect farms further from the homestead as opposed to farmers who are 'resource richer' who can afford to have resources enough for all the farms they have.

Maize yield positive association with the use of animal manure (Table III) in maize cultivation implies that a household with high maize yield was more likely to use animal manure in maize cultivation. Animal manure has been long known to improve soil fertility and increase yield (Mucheru-Muna *et al*., 2014; Ajayi *et al*., 2007; Mucheru-Muna *et al*., 2007). Good yields can allow a farmer to sell excess produce and purchase livestock associated with production of animal manure.

Training had positive effect on the use of animal manure (Table III). This implies that training helps farmers to correctly use animal manure for crop production. In tandem with this observation, Misiko and Ramisch (2007) noted that integrated soil fertility management strategies have been met with major challenges because they are knowledge-intensive and their adaptations and applications are diverse (Adolwa *et al*., 2012), often requiring training for proper utilization. Macharia *et al*. (2012) also emphasizes that having knowledge on a technology puts a farmer at a position to use the technology.

Socio-demographic factors affecting use of combined inorganic and organic manure with improved seeds among farmers in Runyenjes sub-County

Regression results showed that size of land under maize (negative), household labour (positive), off farm income (negative) and tropical livestock unit (positive) had significantly statistical association with the use of combined inorganic fertilizer and animal manure with improved seeds (Table IV). Size of land under maize was negatively associated with the use of combined inorganic fertilizer and animal manure with improved seeds (Table 5). This shows that household with larger sizes of land under maize were less likely to use a combination of inorganic fertilizer and animal manure with improved seeds in maize cultivation. And although farmers owning large pieces of land are associated with use of technologies (Barret and Marenya, 2007; Mugwe *et al*., 2008), this is otherwise for farmers with large pieces of land under maize crop. Demand of resources and inputs associated with a large piece of land under maize can hinder a household's ability to acquire them. Macharia *et al*. (2012) also found farm size to be a negative predictor as adoption increased with decrease in farm size.

Enough household labour was a significant factor influencing use of combined inorganic fertilizer and animal manure with improved seeds for maize production (Table IV). Households with enough and available family labour have been known to use technologies. Marenya and Barret, (2007) agrees that enough family labour reduces a household dependence on hired labor that often also requires supervision. Mugwe *et al*. (2008) mentioned household labor as a factor immensely influencing adoption of soil management technologies.

Having an off-farm earning was negatively associated with the combined use of inorganic fertilizer and animal manure with improved seeds (Table IV). Farmers with off-farm incomes were less likely to use a combination of inorganic fertilizer and animal manure with improved seeds. Adolwa *et al*. (2012) explains that it is probable that individuals with higher off-farm incomes invested their time, energies and money in non-farm activities at the expense of ISFM, hence the disparity with other studies. It is thus not surprising that Reardon *et al*. (2000) identified having an off-farm income as one of the reasons for farmers' failure to adopt hybrid maize in Botswana.

Tropical livestock unit had positive significant association with the combination of inorganic fertilizer and animal manure with improved seeds for maize production (Table IV). This implies that a household with a higher livestock number is more likely to use a combination of inorganic fertilizer and animal manure with improved seeds in maize production. Livestock is very crucial in a farming system as it is the major source of manure and draft power (Adolwa *et al*., 2012). Livestock ownership is an indication of wealth status of small holder farmers (Adolwa *et al*., 2012; Zingore *et al*., 2007). Farmers can sell portions of their livestock to acquire maize inputs, as livestock and household assets increase the availability of capital which makes investment in land-enhancing technologies feasible (Akinola *et al*., 2010).

Soil fertility status of maize farms in Runyenjes sub-County

Soil analysis results indicated that all the farms surveyed had moderately acidic soils with pH ranging from 4.59 to 6.95 with a mean of 5.60 (Table V). The mean available phosphorus level in the study area as 39.75 ppm P indicating moderate levels of the nutrient. The available P observations were evenly distributed. The interquartile range for available P lied between 35 and 40 ppm while the median was about 35 ppm (data not shown). The soils had 0.21% total N, 2.21% total OC, 1.12% K, 5.9% Ca, 2.44% Mg, 1.04% Mn and 0.62% Na (Table 6). The soils also had Cu, Fe, Zn ions of 4.62, 26.07 and 28.01 respectively (Table V).

Farmer management factors affecting phosphorus levels in farm soils of Runyenjes sub-County

Regression results showed that amount of NPK 23:23:0, intercropping of maize, liming, and total land owned as positive significant management factors affecting amounts of available P in farmer soils (Table VI). The amount of NPK 23:23:0 a farmer applied on his maize farm had significant and positive associations with the amounts of available P in small holder farms in the study area. This means that a farmer who applied more NPK 23:23:0 on his maize farm was more likely to have a farm with high levels of available P. High phosphorus (P) fixation is a serious problems in Africa, and although phosphatic fertilizers are imported and costly for the average farmer (Yamoah *et al*., 1996), it is one of the most viable and practical way of increasing phosphorus levels in the soil.

Intercropping of maize with a legume was found to be a positive predictor of whether levels of available phosphorus were high in small holder farms in Runyenjes sub-County (Table VI). This implied that farmers who intercropped their maize with other legumes were more likely to have high amounts of available P in their maize farms. Synergies between N (probably added by legume intercrop) and P nutrients allow for more uptake of P than sole P application. Ademba *et al*. (2015) explained that there is higher P nutrient availability with combined N and P than the sole P application, and this could be attributed to the synergistic N enhancement of P uptake.

Liming of soil by a small holder farmer was found to be statistically significant and positively associated with high available P amounts (Table VI). This shows the more a farmer applied lime to reduce soil acidity, the more the amount of available P. Sustainable agriculture is threatened by widespread acidity in many parts (Yamoah *et al*., 1996), however application of lime has been reported to significantly improve soil fertility (Nduwumuremyi *et al*., 2013). In regards to this, liming must be done considerably. For example, Yamoah *et al*. (1996) explains that experimental results showed that liming was most effective at low P rates and its effect on yield diminished with increasing P fertilization. Reduced acidity results in more nutrient availability, especially of nutrients prone to leaching and movement during rainfall. Mbakaya *et al*. (2011) explains that acidity has been found to retard plant growth through H^+ and Al^{3+} ionic effects, mineral ion toxicity or by indirectly interfering with mineral availability.

TABLES

Table I: Fertilizer application among farmers in Runyenjes sub-County

Type of application	**Percentage (N=100)**
Sole DAP application	3
Sole NPK application	1
Sole CAN application	0
Sole manure application	2
Combined DAP + NPK only	7
Combined DAP + CAN only	3
Combined NPK + CAN only	1
Combined DAP + NPK + CAN only	3
Combined DAP + manure only	7
Combined NPK + manure only	15
Combined CAN + manure only	1
Combined DAP + NPK + manure	22
Combined DAP + CAN + manure	7
Combined NPK + CAN + manure	6
Combined DAP + NPK + CAN + manure	18
No input	4

Fertilizer input	**Percentage**	**Rate of use among users**	**Rate of use among whole**

			sample
DAP	70	87.76	63.84
NPK 23:23:0	73	109.67	87.73
CAN	38	94.13	35.77

Table II: Socio-demographic factors affecting amounts of phosphorus fertilizer used by farmers in Runyenjes sub-County

Independent variables	B	S.E.	Beta	t	Sig.
(Constant)	250.227	82.164		3.045	0.003
HHH gender	-15.775	24.824	-0.058	-0.635	0.527
HHH age	-0.650	1.221	-0.081	-0.532	0.596
HHH education	-20.209	15.564	-0.133	-1.298	0.198
HHH occupation	-22.865	17.316	-0.127	-1.320	0.190
HH size	8.979	4.837	0.185	1.856	0.067*
Farming experience (yrs)	-0.382	1.160	-0.053	-0.330	0.742
Total land owned (ha)	0.430	2.916	0.015	0.148	0.883
Size of land under maize (ha)	-41.467	14.301	-0.328	-2.900	0.005***
Off-farm earnings (Ksh)	16.130	6.364	0.236	2.534	0.013**
Tropical Livestock Unit	4.428	9.213	0.046	0.481	0.632
Yield (t/ha)	30.660	12.605	0.226	2.432	0.017**

Dependent Variable: Amount of phosphorus fertilizer applied per season

N =100, ***Significant at 1% probability level, **Significant at 5% probability level, *Significant at 10% probability

Table III: Socio-demographic factors influencing use of animal manure among farmers in Runyenjes sub-County

Independent variables	B	S.E.	Beta	t	Sig.
(Constant)	0.201	1.134		0.178	0.859
HHH gender	-0.386	0.270	-0.139	-1.428	0.157
HHH education	0.056	0.165	0.036	0.339	0.735
HHH occupation	-0.586	0.306	-0.192	-1.918	0.058*
HH size	0.060	0.051	0.123	1.184	0.240
Farming experience (yrs)	0.002	0.013	0.028	0.163	0.871
Size of land under maize (ha)	0.495	0.127	0.386	3.885	0.000***
Off farm earnings (Ksh)	0.138	0.069	0.199	2.016	0.047**
Maize yield in (t/ha)	0.275	0.134	0.200	2.053	0.043**
Training on animal manure	0.477	0.285	0.154	1.674	0.098*

a. Dependent Variable: use of animal manure (TLU)

N =100, ***Significant at 1% probability level, **Significant at 5% probability level, *Significant at 10% probability

Table IV: Socio-demographic factors affecting use of combined inorganic, animal manure and improved seeds among farmers in Runyenjes sub-County

Independent variables	**B**	**S.E.**	**Beta**	**t**	**Sig.**
(Constant)	0.317	0.363		0.874	0.384
HHH gender	-0.140	0.097	-0.149	-1.445	0.152
HHH age	-0.006	0.005	-0.209	-1.187	0.238
HHH education	0.062	0.058	0.118	1.064	0.290
HHH occupation	0.058	0.111	0.057	0.528	0.599
HH size	0.028	0.018	0.167	1.576	0.118
Farming experience	0.007	0.005	0.290	1.546	0.126
Size of land under maize	-0.133	0.047	-0.307	-2.857	0.005**
Enough HH labour	0.266	0.105	0.258	2.548	0.013**
Off farm earnings	-0.043	0.025	-0.182	-1.704	0.092*
TLU	0.099	0.036	0.291	2.726	0.008**

a. Dependent Variable: combined use of inorganic fertilizer, animal manure and improved seeds
N =100, **Significant at 5% probability level, *Significant at 10% probability

Table V: Soil properties of maize farms in Runyenjes sub-County

Parameters (Soil chemical properties)	Value
Soil pH	5.60
Total Nitrogen %	0.21
Total Organic Carbon %	2.21
Phosphorus in mg/kg	39.75
Potassium me%	1.12
Calcium me%	5.9
Magnesium me%	2.44
Manganese me%	1.04
Copper ppm	4.62
Iron ppm	26.07
Zinc ppm	28.01
Sodium me%	0.62

Table VI: Farmers management factors affecting available phosphorus amounts in maize farms of Runyenjes sub-County

Independent variable	β	S.E.	Beta	T	Sig.
(Constant)	66.254	36.888		1.796	0.076
Amount of DAP applied	-0.026	0.099	-0.034	-0.259	0.796
Amount of NPK 23:23:0 applied	0.137	0.082	0.200	1.683	0.096*
Amount TSP applied	-0.122	0.343	-0.040	-0.357	0.722
Amount CAN applied	0.022	0.063	0.050	0.343	0.732
Amount of foliar applied	5.571	10.878	0.086	0.512	0.610
Intercropping of maize	11.301	5.474	0.227	2.064	0.042**
Continuous P application	4.287	4.832	0.098	0.887	0.378
Animal manure use	-3.663	7.676	-0.059	-0.477	0.634
Liming of soil	46.442	17.684	0.368	2.626	0.010***
Training on inorganic fertilizer	2.980	3.087	0.114	0.965	0.337
Training on animal manure	-5.290	6.641	-0.098	-0.796	0.428
Size of land under maize	-3.805	2.995	-0.171	-1.270	0.207

Dependent Variable: P in mg/kg

N =100, **Significant at 5% probability level, *Significant at 10% probability level

CONCLUSIONS AND RECOMMENDATIONS

The implications of these results are that research should put into consideration the demographic and socioeconomic status of farmers during the coining of yield increasing technologies to ensure that the needs of all the small holder farmers are addressed. In regards to education level, researchers and extension workers can aim to disseminate integrated soil fertility management information in disintegrated forms that can be understood and incorporated by small holder farmers who have low literacy levels. The gender aspect should be considered and trainers should ensure that both female and male trainees are well represented during trainings and workshops. It is also important for governments to provide off-farm opportunities as off-farm income is important in the adoption of yield increasing strategies. To increase available P levels for maize production in small holder farms, farmers must be empowered to be able to access inorganic fertilizer, they should also be capacitated to access lime that reduces acidity on the farms and to use organic amendments. Farmers should also be encouraged to intercrop or rotate their maize crop with legumes as the positive interaction will not only increase yields but improve nutrients in the soil. Extensive grassroot support must be explored and encouraged to ensure that farmers adopt fully ISFM strategies. Farmers are willing to take up yield increasing strategies but frustrations during implementation due to lack of knowledge coupled with poor grassroot support can lead to abandonment of such strategies. Therefore, all these factors must be incorporated by policy makers, researchers and extension workers to ensure that they are addressed appropriately during formulation of yield increasing technologies.

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5.4 Combining agroforestry with conservation agriculture for soil fertility enhancement in the dryland context: case of Machakos County, Kenya

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ABSTRACT

Kenyan drylands are faced with challenges of land and vegetation degradation, have low productivity, limited majorly by moisture, then soil nutrients. Conservation agriculture with trees is one opportunity to redress these challenges through minimum tillage, soil cover and crop rotation. The study examined the differences in soil properties between conservation agriculture (CA) and conventional agriculture (COA) both with and without trees at an onsite experiment station in Machakos, Kenya over three seasons (SR 2013, LR 2014 and SR 2014). A randomized complete block design experiment was laid with 2 blocks (CA and COA) and ten treatments replicated thrice. *Calliandra calothyrsus* Meissn. and *Gliricidia sepium* Jacq.) were planted in three different spatial patterns (1.5 m x 1 m, 3 m x 1 m, and 4.5 m x 1 m) for maize-legume intercrops. Soil samples were taken in October 2015 from top and sub soil and analyzed for selected physical and chemical characteristics using standard laboratory procedures. Data was subjected to analysis of variance for significant relations and differences, aided by Genstat software version 14. Fisher's least significant difference test was used to separate treatment means at 5% alpha level. Results showed significant increase in soil moisture under conservation agriculture with trees. Sole CA retained more moisture than sole COA (31.56 and 26.54% vol. respectively, p<0.001). Nitrogen, organic carbon, sodium and potassium were higher under CA while cation exchange capacity (CEC) was significantly (p=0.004) higher (14.372 $cmol_c/kg$) in COA than in CA (12.718 $cmol_c/kg$), and strongly correlated with clay content (r=+0.869). Exchangeable calcium and magnesium were also significant under COA, which also had higher soil salt content (electrical conductivity) and phosphorus levels. Bulk density at the surface layer was higher under COA than CA but not significant (p=0.97).Conclusively; both conservation and conventional practice enhance soil fertility with an improvement in majority of the soil properties noted under CA, making CA a more preferred option for enhancing soil heath in the dry-lands.

Key words: Conservation agriculture with trees; Conventional agriculture; spatial patterns; *Calliandra calothyrsus*; *Gliricidia sepium*; soil health

INTRODUCTION

The soils of the arid and semi arid areas all over the World are known for historic degradation (Lal, 2011) .These zones are also prone to vegetation destruction as a result of the disproportionate human disturbance (Curtin *et al*., 2002) and soil erosion which are responsible for their reduced primary productivity (Reynolds *et al*., 2007) which will continue to decline (Parr *et al*., 1990; Enfors *et al*., 2008).There also occurs general land degradation as a result of poor land management and this has become a development and environmental issue of global concern (Zika and Erb, 2009).With these regard, strategies that are needed to cope with the challenges of the drylands must address the challenges of moisture limitations and the general degradation. Of primary importance are the strategies that offer better soil and water management in these areas if the productivity is to be sufficiently increased (Bryan *et al*., 2009; Dixon *et al*., 2013)

Agroforestry systems suffice as an option for the drylands since they are sustainable land use alternatives ,tending to imitate natural system characteristics especially those that are beneficial to soil and enhance the well-being thereof (Tornquist *et al.,* 1999). In fact, the potential of agroforestry systems as a means of achieving sustainable land use has been promoted since the 1980s (Kursten, 2000) and has since been widely and progressively integrated into good farming practice. These systems either with or without conservation agriculture (CA) therefore have a considerable influence on soil properties. Mitchell *et al*. (2007) (as cited in Garland *et al*., 2011) and Ketema and Yimer (2014) noted that no tillage practices increases soil quality, water quality and organic carbon thereby enhancing carbon sequestration to reduce emissions. Makumba *et al*. (2007) also realized increased soil organic carbon in Gliricidia based system in comparison to sole maize, emphasizing the importance of tree integration into farms.

Further more, Jose (2009) show that the role of agroforestry in biological fixation of nitrogen is a common phenomenon in the tropical areas. Even in the case of non N-fixing trees, the soil properties in entirety are still enhanced as has been noted by other researchers (Schroth and Sinclair, 2003; Jose *et al*., 2004). Soil porosity (amount of pores) has been found to be greater to the tune of 5 times in tree based systems alongside increase in enzyme activities (Udawatta *et al*, 2008) which also have been shown to improve organic matter and microbial biomass of soils (Lee and Jose, 2003).The high organic matter in agroforestry and conservation tillage systems (Palm *et al*., 2014) is also known to improve soil porosity, aggregate and structure, contrary to conventional tillage that brings about discontinuity in pore space between cultivated layer and the sub layers of the soil (Yimer *et al*., 2008). Ketema and Yimer (2014) in their study additionally noted low bulk density in agroforestry based conservation tillage compared to maize based conventional tillage (1.09 gcm^3 and 1.18gcm^3, respectively). The high bulk density in conventional farming is contributed to by continuous tillage which causes structural deterioration; mineralization of soil organic matter and compaction due to lower infiltration rates (Yimer *et al*., 2008).In accordance with the study of Harvey *et al*. (2006), the integration of trees into farming systems has also been known to lead to considerable conservation of soil biodiversity.

Moreover, agroforestry based conservation agriculture improves soil moisture content due to less exposure of soil to the direct impacts of sunlight thus a reduced evapotranspiration rate, meaning more of the moisture is able to be maintained within the soil (Ketema and Yimer, 2014; Seobi *et al*., 2005). Minimum tillage and maintenance of permanent soil cover, which are among the two principles of conservation agriculture have also been known to be moderators of the surface conditions of land, leading to improved yields, surface runoff control, increased net benefits as a result of the reduction in the costs of production, moderating soil temperatures as well as enhancing the rooting of crops (Gill *et al.,* 1996; Govaerts *et al.,* 2009). The retention of residue on the soil also lead to greater soil organic carbon in the soil surface as compared to removal of such residues which deteriorates the organic matter dynamics thus perpetuating soil carbon loss and impacting low fertility as was realized in a study by Guto *et al*. (2011).

MATERIALS AND METHODS

The study was carried out at the Machakos Agricultural Training Centre (coordinates E037°14.303' and S 01°32.738'), and utilized a randomized complete block design experiment with two blocks (conservation agriculture (CA) and conventional agriculture (COA)) with ten treatments replicated thrice, summing to 60 plots measuring 12m by 12 m. The treatments included *Calliandra calothyrsus, Gliricidia sepium* and pigeon peas (*Cajanas cajan)* at three spatial patterns i.e. 1.5m × 1m, 3 m ×1m and 4.5m × 1m; and control. The trees were integrated within maize-legume intercrops. Delta T capacitance probe access tubes were installed in every plot, and moisture readings taken fortnightly. The experiment ran from short rains (SR) 2013 to short rains 2014. In October 2015, composite soil samples were taken from 5 spots within all the plots at depths of 10-30cm. Two Soil profiles were also dug each at a control plot within both blocks and sampled for bulk density at depth intervals of 20cm, up to 120cm depth. The samples were analyzed for organic carbon and nitrogen, total carbon and nitrogen, soil texture, cation exchange capacity, electrical conductivity, pH (using standard methods described by Anderson and Ingram (1993)), extractable P, Ca, Mg, K & Na and exchangeable bases (using Mehlich III extraction method (Mehlich, 1984)).The analyses followed the standard operation procedures of the World Agroforestry Centre Plant-Soil Spectral analysis laboratories.

The data was subjected to analysis of variance using Genstat software version 14 and the parameters were considered significant at $p<=0.005$. Different in means of soil parameters between blocks and treatments were separated using Fisher's least significant difference test.

RESULTS AND DISCUSSION

Soil moisture

Soil moisture retention was found to be generally higher in conservation agriculture (CA) trials compared to conventional agriculture (COA) in all the three seasons (Figure 1), and statistically significant (p<0.001) (Table I). CA recorded grand mean moisture retention of 31.56 % vol. against COA's 26.24 % vol. Reducing tree spacing increased moisture retention, with *Calliandra* at 1.5 m showing high moisture rates under CA (40.25% vol.) compared to the same treatment under COA (29.67% vol.) (Table I). Moisture consistently increased after each season (Table I) and was significant among seasons (p=0.03) and treatments (p<0.001).

Cation Exchange Capacity (CEC)

CEC was not significant among treatments (p=0.641) but was significant between blocks (COA=14.39 $cmol_c$/kg and CA=12.75 $cmol_c$/kg, p=0.004) (Table II).The lowest CEC was in Calliandra at 1.5m (9.11 $cmol_c$/kg) under CA and the highest in Pigeon peas at 4.5m (15.35 $cmol_c$/kg) under COA. There was no CEC below 5 $cmol_c$/kg (which's normally considered very low (Landon, 1991).

Bulk Density (BD)

Bulk density was also not significant among treatments and between blocks. Mean BD for CA was 0.971g/cm^3 while that for COA was 0.92g/cm^3 (p=0.18).Calliandra spaced at 4.5m had the highest BD of 1.37g/cm^3 under CA and the lowest being 0.877g/cm^3 for pigeon peas at 1.5m under COA (Table III).Comparison of BD down the soil profile for both blocks did not reveal any statistical difference though the grand mean BD for COA was slightly higher than CA (0.945 and 0.88 gcm^3 respectively) as shown in Table III.

Electrical Conductivity (Ecd)

The study revealed higher (and not significant) amounts of soil in COA system than in CA (COA=0.0627 dS m^-1 and 0.5406 dS m^-1 respectively; p=0.33) (Table II). Intervention with trees at different spacings moreover did not differently affect salinity of the soils both under CA and COA (p =0.503), although the electrical conductivity in Calliandra at 4.5m under CA was a high of 4.715 dS m^-1.

Soil pH (water)

The highest pH was recorded at Calliandra at 4.5m under CA (13.6) while the lowest was at Calliandra at 1.5m under COA (6.93).CA had higher pH than COA (7.6 and 7.1 respectively), though the difference was not significant (p=0.391) as is in Table II. Tillage did not affect pH.

Exchangeable bases

Mehlich 3 phosphorus (m3.P), sodium (ExNa) and potassium (ExK) were more available under CA compared to COA. On the other hand, exchangeable calcium (ExCa) and magnesium (ExMg) were significantly higher in COA than in CA ($p<0.001$) (Table IV). Intervention with trees both in CA and COA also led to more nutrient availability as compared to control treatments.

Soil Texture

The percentage of sand, silt and clay were not statistically different. However, the clay content was found to be strongly positively correlated to the Cation Exchange Capacity (CEC) of the soil (correlation coefficient =0.869), an implication that clay content increases CEC. This phenomenon of CEC increasing with the amount of clay was evident in the study where the treatment with the lowest clay content of 57% (Calliandra at 4.5m under CA) recorded the lowest CEC of 9.11Cmol$_c$/kg (Table V).Individual treatment means were not significant between farming systems CA and COA.

Carbon and Nitrogen

CA had more Nitrogen both total (TN) and Organic (ON) compared to COA (TN=0.17% for CA and 0.12 % for COA; ON =0.16% for CA and 0.11% for COA).Total Carbon (TC) was however higher under COA (Table VI) but was not significant ($p=0.07$).

The high moisture content experienced under CA with trees is due to the adequate vegetative soil cover provided by the tree component and plant residue and therefore evapotranspiration was reduced in these treatments, thus more moisture retained. Ketema and Yimer (2014) argued that agroforestry practices certainly improve soil moisture. High moisture under CA tallies with the studies of other researchers (Thierfelder and Wall, 2009). CA significantly increases soil water availability and thus higher moisture content (Corbeels *et al*., 2014), and also as result of mulch and minimum soil disturbance (Thierfelder *et al*., 2013; Rockstrom *et al*., 2009).The incorporation of trees into CA systems is therefore further proven in this study as an apt option for moisture retention and soil improvement.

The of results on the soil physical and chemical properties point to a general acceptance that CA has led to much improvement of soil quality compared to COA though majority are not significantly high. The lack of statistical significance in the properties does not however infer lack of practical importance in the greater values recorded, which is in line with other studies. Mloza-Banda *et al.* (2016) for instance in a study to compare tillage effects of CA and ridge tillage did not find any significance though CA had lower bulk density than ridge tillage (1.49-1.58 Mg m^{-3} and 1.53- 1.59 Mg m^{-3} respectively).Comparatively to the study of Mloza-Banda *et al* .(2016), the study found lower BD at the top most soil layer (0-20cm) in CA than in COA (0.937 and 0.985g/cm^3 respectively *p*=0.97) .This can be attributed to cultivation induced compaction in the COA practice.

Soil pH not being affected by tillage in the study is in tandem with the findings of other researchers (Rasmussen, 1999; Busari *et al.,* 2015).However, pH was very crucial in effectuation of CEC, the correlation of which is negatively strong (coefficient= -0.8258), where higher pH translated to very low CEC and vise versa. This is also reinforced by the study of Schwab *et al.* (2015) in which they ascribed low CEC in their samples to low pH. Different researchers have found conflicting results on the effects of tillage on pH. Rahman *et al.* (2008) found it to be lower in no-till systems (a form of CA) than in Conventional tillage and attributed this to accumulation of organic matter and elevation in electrolyte concentration while Lal (1997) found it to be conversely high in no-till systems compared to conventional systems.

The high carbon and nitrogen in CA over COA can be attributed to minimum soil disturbance which lessens the destruction of soil structure and aggregate exposure. This in turn means that less of the inherent organic matter is decomposed and therefore the ultimate result is more organic carbon and total nitrogen maintained in the soil compared to COA where the opposite is true (Xue *et al*., 2015; Małecka *et al.*, 2012).Control treatments exhibited among the lowest values of carbon and nitrogen, proving that interventions with trees enhanced carbon and nitrogen availability, further stressing the importance of incorporation of trees into croplands in improvement of soil carbon and nitrogen among other soil physical and chemical properties (Nair *et al.,* 2009).Owing to the fact that nitrogen is one of the major nutrient inhibiting plant growth in dryland ecosystems (Sainju *et al*., 2009), the high values obtained under CA in this study is sufficient proof of the capability of CA to enhance nitrogen in the dryland context. The less carbon obtained under COA can also be ascribed to soil disturbance through tillage which has been documented in literature to be the sole cause of persistent soil carbon losses (Baker *et al*., 2007; Reicosky, 2003)

Sodium and potassium were also found to be high under CA compared COA and this can be attributed go the fact that the tillage layer of soil is less destroyed and also because there was residue (maize, legume and tree biomass) which was returned back to the soil during the experimentation period in CA and totally removed in COA (Tan *et al*. 2015). Reverting back biomass to the soil therefore could have led to the enrichment of the nutrients and thus explains the higher levels of N, K and Na under CA than COA. This is well agreed since CA yielded much more biomass in leaf and wood than COA in the study. The importance of agroforestry and maintenance of crop cover (thus CAWT) in building healthy fertile soils is therefore once again stressed in this study as it was in Garrity *et al*. (2010).

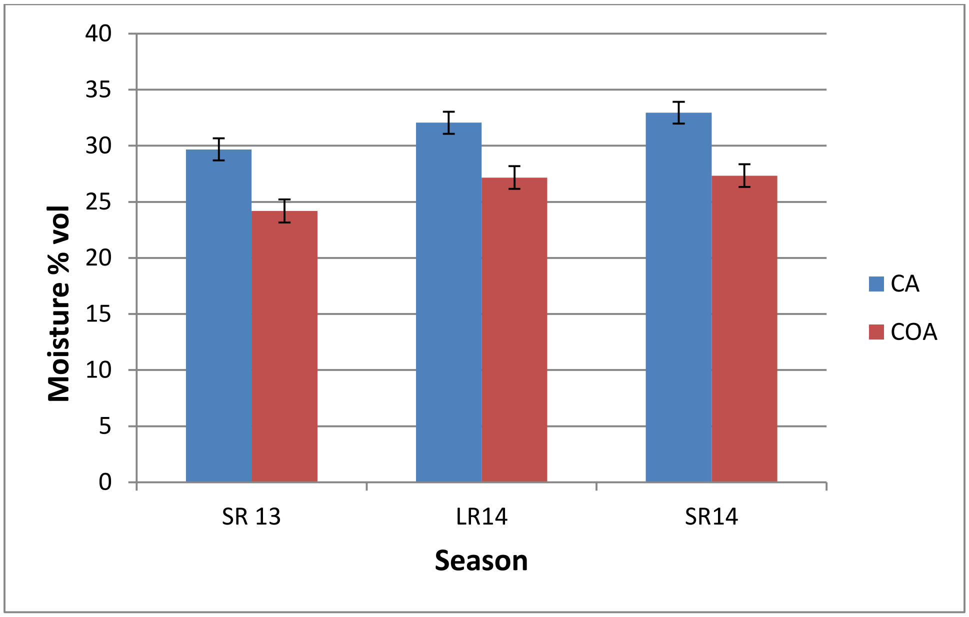

Figure 1: Comparison of soil moisture content between CA and COA in Machakos

TABLES

Table I: Moisture retention during the SR13, LR14 and SR14 seasons in Machakos

Treatment	Mean treatment moisture retention % vol.	Retention by season (% vol.)			Retention by farming system (% vol.)	
		SR 2013	LR 2014	SR 2014	CA	COA
calliandra at 1.5m	34.96^{a}	32.73^{abcd}	35.73^{ab}	36.42^{a}	40.25^{a}	29.67^{cd}
calliandra at 3m	28.52^{bcd}	26.96^{cdef}	28.96^{abcdef}	29.64^{abcdef}	31.21^{c}	25.83^{ef}
calliandra at 4.5m	31.99^{ab}	28.6^{abcdef}	34.6^{abc}	32.78^{abcd}	31.66^{c}	32.63^{c}
Gliricidia at 1.5m	29.24^{bcd}	27.68^{cdef}	29.68^{abcdef}	30.37^{abcdef}	32.23^{c}	26.65^{ef}
Gliricidia at 3m	32.67^{ab}	30.17^{abcdef}	33.57^{abc}	34.26^{abc}	37.64^{ab}	27.7^{def}
Gliricidia at 4.5m	29.43^{bc}	27.8^{bcdef}	29.9^{abcdef}	30.58^{abcde}	36.96^{b}	21.9^{gh}
pigeon pea at 1.5m	26.6^{cd}	24.38^{ef}	27.38^{cdef}	28.06^{bcdef}	27.91^{de}	27.87^{ef}
pigeon pea at 3m	26.54^{cd}	25.48^{def}	26.72^{cdef}	27.41^{cdef}	29.45^{ef}	27.62^{def}
pigeon pea at 4.5m	24.17^{d}	22.61^{f}	24.61^{ef}	25.29^{def}	27.87^{def}	20.47^{h}
control	24.87^{cd}	22.97^{ef}	24.97^{def}	26.66^{cdef}	24.75^{fg}	24.99^{efg}
p	**<0.001**	**0.031**	**0.031**	**0.031**	**<0.001**	**<0.001**
LSD	**5.188**	**2.513**	**2.513**	**2.513**	**0.995**	**0.995**

*Means with same superscript letters are not different from each other,*significant at p<0.005. CA and COA denote conservation agriculture and conventional agriculture respectively.*

Table II: Soil Chemical properties between conservation agriculture and conventional agriculture in Machakos for the period SR 2013 to SR 2014

Farming system	**Conservation Agriculture**				**Conventional Agriculture**				**t-test *p* values**			
									PH	**Ecd**	**CEC**	**BD**
Treatment	**pH**	**Ecd (dSm^{-1})**	**CEC ($cmol_c/kg$)**	**BD (g/cm^3)**	**pH**	**Ecd (dSm^{-1})**	**CEC ($cmol_c/kg$)**	**BD (g/cm^3)**				
Calliandra at 1.5m	6.957	0.057	12.854	0.956	6.934	0.062	14.031	0.914	0.99	0.99	0.82	0.98
Calliandra at 3.0m	7.080	0.054	13.970	0.902	7.188	0.047	14.841	0.943	0.98	0.98	0.87	0.98
Calliandra at 4.5m	13.576	4.715	9.111	1.307	7.130	0.056	14.382	0.917	0.15	***0.03**	0.28	0.79
control	6.910	0.059	12.321	0.926	7.147	0.056	13.874	0.943	0.95	0.99	0.76	0.99
Gliricidia at 1.5m	6.936	0.062	13.585	0.927	7.111	0.114	14.617	0.903	0.96	0.9	0.84	0.99
Gliricidia at 3.0m	6.957	0.076	13.278	0.895	7.015	0.056	14.349	0.944	0.99	0.96	0.84	0.97
Gliricidia at 4.5m	7.006	0.052	13.978	0.940	7.005	0.060	13.605	0.961	0.99	0.98	0.94	0.99
Pigeon pea at 1.5m	7.051	0.049	14.007	0.969	7.124	0.058	13.785	0.877	0.98	0.98	0.97	0.95
Pigeon pea at 3m	6.913	0.057	12.225	0.944	6.994	0.054	15.040	0.921	0.82	0.99	0.59	0.99
Pigeon pea at 4.5m	6.968	0.061	12.862	0.927	6.973	0.061	15.348	0.882	0.99	ND	0.64	0.97
LSD	**1.402**	**3.154**	**2.446**	**0.243**	**1.402**	**3.154**	**2.446**	**0.243**				
p	0.391	0.33	***0.004**	0.18	0.391	0.33	***0.004**	0.18				

* *Significant at p<=0.05,SD = Least significant difference, ND denotes no difference between means*

Table III: Bulk density down the soil profile between conservation agriculture and conventional agriculture in Machakos over study period SR 2013 to SR 2014

Profile Depth	**Farming system**		**t-test; p values**
	CA	COA	
0-20cm	0.937	0.985	0.97
20-40cm	0.880	0.953	0.96
40-60cm	0.836	0.955	0.93
60-80cm	0.870	0.947	0.96
80-100cm	0.857	0.982	0.93
100-120cm	0.902	0.849	0.97
p	**0.603NS**	**0.603NS**	
SED	**0.458**	**0.458**	

NS: Not significant at p<=0.05

Table IV: Exchangeable bases availability among treatments and between farming systems in Machakos over the study period SR 2013 to SR 2014

Farming system	**Conservation agriculture**					**Conventional Agriculture**				
Treatment	**m3.P (mg /kg)**	**ExNa ($cmol_c$/kg)**	**ExCa ($cmol_c$/kg)**	**ExMg ($cmol_c$/kg)**	**ExK ($cmol_c$/kg)**	**m3.P (mg /kg)**	**ExNa ($cmol_c$/kg)**	**ExCa ($cmol_c$/kg)**	**ExMg ($cmol_c$/kg)**	**ExK ($cmol_c$/kg)**
Calliandra at 1.5m	26.811	0.115	7.094	2.501	1.904	25.828	0.113	7.925	2.624	1.942
Calliandra at 3m	22.842	0.150	7.817	2.633	1.977	20.840	0.171	9.093	2.912	1.772
Calliandra at 4.5m	13.417	2.752	6.205	2.440	5.147	26.653	0.142	8.310	2.564	2.088
control	27.494	0.116	6.661	2.398	1.881	23.307	0.130	8.473	2.957	1.720
Gliricidia at 1.5m	25.315	0.121	7.441	2.550	2.019	26.157	0.154	8.466	2.731	2.129
Gliricidia at3m	28.816	0.144	6.858	2.356	2.247	23.228	0.134	8.201	2.766	1.897
Gliricidia at 4.5m	25.636	0.141	7.946	2.532	1.897	27.017	0.118	7.869	2.685	1.894
Pigeon pea at 1.5m	25.137	0.151	8.393	2.697	1.874	22.810	0.147	7.931	2.541	1.957
Pigeon pea at 3m	26.103	0.120	6.702	2.283	1.822	24.333	0.142	8.639	2.793	1.992
Pigeon pea at 4.5m	22.237	0.109	7.036	2.631	1.965	25.062	0.138	8.803	2.983	2.028
Mean	**24.467**	**0.399**	***7.136**	***2.483**	**2.282**	**24.651**	**0.138**	***8.346**	***2.750**	**1.948**
p	**0.86**	**0.341**	**<0.001**	**<0.001**	**0.338**	**0.86**	**0.341**	**<0.001**	**<0.001**	**0.338**
LSD	**2.728**	**0.555**	**0.584**	**0.146**	**0.715**	**2.728**	**0.555**	**0.584**	**0.146**	**0.715**

*** Significant at p <0.005**

Table V: Composition of sand, silt and clay between conservation and conventional agriculture in Machakos for the period SR 2013 to SR 2014

Farming system	**CA**			**COA**			**t-test, p values**		
Treatment	**Clay (% vol.)**	**Silt (% vol.)**	**Sand (% vol.)**	**Clay (% vol.)**	**Silt (% vol.)**	**Sand (% vol.)**	**Clay**	**silt**	**sand**
Calliandra 1.5m	75	19	17	75	20	17	ND	0.87	ND
Calliandra 3.0m	77	19	15	78	18	15	0.93	0.87	ND
Calliandra 4.5m	57	18	11	76	20	16	0.09	0.75	0.34
control	74	20	18	75	19	18	0.93	0.87	ND
Gliricidia 1.5m	75	19	17	76	19	16	0.93	ND	0.86
Gliricidia 3.0m	75	20	16	76	19	17	0.93	0.87	0.86
Gliricidia 4.5m	75	20	17	75	20	18	ND	ND	0.87
Pigeon peas 1.5m	76	19	17	77	19	16	0.94	ND	0.86
Pigeon peas 3.0m	74	20	18	76	19	16	0.87	0.87	0.73
Pigeon peas 4.5m	78	18	16	76	19	16	0.87	0.87	ND
SED	**0.281**	**0.633**	**2.251**	**0.281**	**0.633**	**2.251**			

ND denotes no difference between individual treatment means between farming systems

Table VI: Carbon and Nitrogen differences between conservation agriculture and conventional practice in Machakos for the period SR 2013 –SR 2014

Farming System	Conservation Agriculture				Conventional Agriculture		
Treatment	TN (%weight)	TC (%weight)	ON (%weight)	OC (%weight)	TN (%weight)	TC (%weight)	ON (%weight)
Calliandra(1.5m)	0.12	1.64	0.11	1.49	0.12	1.77	0.11
Calliandra(3m)	0.12	1.60	0.11	1.48	0.12	1.53	0.11
Calliandra(4.5m)	0.64	1.07	0.58	25.81	0.13	1.71	0.12
control	0.12	1.65	0.11	1.50	0.12	1.59	0.11
Gliricidia(1.5m)	0.12	1.74	0.11	1.58	0.13	1.77	0.12
Gliricidia(3m)	0.12	1.64	0.11	1.49	0.12	1.69	0.11
Gliricidia(4.5m)	0.12	1.66	0.11	1.51	0.11	1.65	0.11
Pigeon pea(1.5m)	0.11	1.59	0.11	1.46	0.11	1.51	0.11
Pigeon pea(3m)	0.11	1.60	0.11	1.45	0.13	1.75	0.11
Pigeon pea(4.5m)	0.11	1.48	0.10	1.31	0.13	1.85	0.12
Mean	**0.17**	**1.57**	**0.16**	**3.99**	**0.12**	**1.69**	**0.11**
p	**0.377**	**0.07**	**0.376**	**0.342**	**0.377**	**0.07**	**0.376**
SED	**0.545**	**0.054**	**0.065**	**0.049**	**0.545**	**0.054**	**0.065**

TN=Total Nitrogen, TC=Total Carbon, OC=Organic carbon, ON=Organic Nitrogen

CONCLUSION

Conclusively, sufficient evidence oozes to back the claim that CA both with and without trees significantly enhances soil moisture compared to conventional farming. CA also enhances amounts of available Nitrogen, Phosphorus and Potassium; and organic carbon. Conventional agriculture on the other hand significantly enhances cation exchange capacity and leads to increased amounts of salts in the soil alongside increase in availability of magnesium, calcium and exchangeable bases. Soil pH, texture and bulk density do not differ between CA and COA although conventional practice increases bulk density at the surface (0-20cm).CA thus surpasses COA in soil fertility enhancement and is thus a preferred option.

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5.5 Effects of selected plant leaf extracts on soil ph and betacarotene levels in amaranthus species grown under varying conditions in Kiambu county

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ABSTRACT
Amaranthus (*Amaranthus spp*.) leaves are a good source of vitamins and source of dietary minerals including calcium, iron, and potassium. Soil pH is a very important chemical property of the soil, as it dictates the availability of plant nutrients. Acidic soils reduce availability of plant nutrients and hinder growth. This is corrected by adding lime which is expensive, does not add nutrients and requires re-application. The objective of this study was to evaluate the effects of leaf extracts from selected tree leaves on soil acidity and beta-carotene levels of amaranthus. Plant leaves that were tested were Turril (*Vitex keniensis*) Mexican sunflower (*Tithonia diversifolia*) and Indian nettle (*Plectranthus barbatus*).The experiment was setup in 2 x 7 factorial arrangement in a randomized complete block design (RCBD) replicated three times. Leaves were dried and soaked in water and extract was added to soil for amanthus grown with plant extracts. Other amaranthus were gown in soils treated with either fertilizer or lime.or manure. Nothing was added. to control soil Beta carotene was determined using UV/Visible instrument. Data was subjected to ANOVA at 5% level of significance using SAS while least significant difference (LSD)used for means separation. Leaf extracts were found to increase betacarotene level of amaranthus to 52.36mg under greenhouse conditions , while those grown with inorganic fertilizer were 21.23mg under irrigation. Soil pH increased from 5.9 to 6.7 for leaf extract treatment and with inorganic fertilizer decreased from 5.9 to 5.3.The outcome, of the research will be used in recommendation of economical organic fertilizer to improve soil pH and increase beta-carotene levels of amaranthus which will benefit small scale farmers who can not afford inorganic fertilizers.
Keywords: Key words: Plant extract, Beta-carotene , Soil pH

INTRODUCTION
There has been a rising demands of African Leafy Vegetables (ALVs) in the recent past in Kenya. The priority species marketed include leafy amaranth (*Amaranthus spp*.), African Black nightshade species (*Solanum spp*.), cowpeas (*Vigna unguiculata*), Ethiopian kale (*Brassica carinata*), kahuhura (*Cucurbita ficifolia*), jute plant (*Corchorus olitorius*) and pumpkin leaves (*Cucurbita maxima and C. moschata*), (Irungu*,et al*, 2011)
African Leafy Vegetables (ALVs) have gained commercial importance over the past 15 years as a result of the enormous growth in market (Irungu *et al*, 2007). ALVs

production has its advantages because of the uniqueness of such as short production cycles thrives in poor soil, are resistant to pests and diseases, require a few purchased inputs, and are quite acceptable to local tastes *(Ekesa,et al, 2009)*

Continuous cultivation of diminishing farms to feed the growing population has resulted in soil degradation and consequently rise in use of inorganic fertilizers to increase crop yield. Increasing and continuous use of inorganic fertilizers lead to lowered soil pH, poor soil texture (Glinsiki and Witold, 1985), poor quality crop yields and finally pollution of the rivers and lakes resulting in eutrophication. The inorganic fertilizers are expensive and hence out of rich to most rural farmers, majority of whom are women. In addition they are not always available, especially the subsidized ones which is being blamed for late planting and thus poor yields. Simulation studies of plant leaves using leaf extracts showed increase in soil pH and crop biomass possibly due to availability of nutrients (Mwangi, 2012; Lawrence, 1990) Also certain plants have litter that can decompose easily releasing plant nutrient and increasing buffering capacity of soil (Murungi, 1990; Njagi 2008; *Njagi et al., 2012*; Kikuchi, 2004, Mwangi, 2012).

However, the study did not look at soil texture or actual crop yield and was under controlled environment. In addition, only a few non-leguminous plants were studied using only a mixture of leaves and leaf extracts. Therefore, there is need to optimize productivity using natural environment and individual as well as combined leaves and leaf extracts to optimize plant nutrients and soil pH. The present study used leaves extract of plants shown to have high buffering capacity and high rate of mineralisation individually for raising pH of the soil as well as adding nutrients to the soil and improving soil texture. Various leaves extracts were tested for their effect on soil pH and nutrients levels. They were used to improve the acidic soils where the amaranthus was grown on improved soils and their growth rate, biomass and yield monitored. Soil pH was also monitored at intervals.

Carotenoids, have been credited with other beneficial effects on human health enhancement of the immune response and reduction of the risk of degerarative diseases such as cancer, cardiovascular diseases,cataract, and macular degeration (Astrog 1997, Bendich 1994, Burri 1997, Gaziano and Hennekens 1993, Krinsky 1993, Mayne 1996, Olson 1999a, Olson and Krinsky 1995). The action of carotenoids against diseases has been attributed to antioxidant property, specifically ,their ability to quench singlet oxygen and interact with free radicals(Palozza and Krinsky 1992).

Therefore it was selected for analysis

It is hoped that the results of this study would be used to improve soil, increase vegetable production, with high levels of betacarotene and alleviate poverty amongst small-scale farmers,as well as encouraging planting of more plants and trees thus increase plant cover especially in Kenya.

General Objective

To determine the effect of selected leaves extracts on soil pH, and betacarotene levels of amaranthus species.

Specific Objectives

(i) To determine the effect of *Vitex keniensis* ,*tithonia diversifolia* and *plectranthus barbatus* leaves extracts on pH of acidic soil.

(ii).To determine levels of betacarotene in amaranthus grown after treatment with leaves extracts of *Vitex keniensis* ,*tithonia diversifolia* and *plectranthus barbatus* ,inorganic fertilizer, lime and with no treatment.

MATERIALS AND METHODS

Study Area and Experiment Procedure

The leaves of the target species were collected from Juja Ward in Kiambu County, where also the experiment was carried out in the field. This was done under three regimes; under irrigation, on rainy season and in a greenhouse at Kenyatta University field demonstration site.

Analysis for soil pH, were done at laboratories in Chemistry Department at Kenyatta University, while for betacarotene analysis was done at JKUAT, Laboratories Food Science Department.

Plant leaves tested were Turrill (*Vitex keniensis*), Mexican sunflower *(Tithonia diversifolia*) and Indian nettle (*Plectranthus barbatus*).The concentration of the leaves extract was 500g diluted with two litres of distilled water.

The leaves were washed, sun dried subjected to milling/hand crushing, weighing packing and labeling. For leave extracts, both milled and hand crushed leaves was soaked in distilled water for 30 days and pH and buffering capacity monitored for individual plant leaves. Optimization of the leaf extracts for soil remediation and growth of the crops was done for open fields. For pH and buffering capacity controls, distilled water was kept under the same conditions and monitored for pH and buffering capacity (Miller and Kissel, 2010).

Study Design and Treatment Application

The experiment setup was in a randomized complete block design (RCBD), in a two by seven factorial. The treatments were the three leaves extracts, lime, Farm Yard Manure inorganic fertilizer and the control.

All the seven treatments were replicated three times.Individual plots measured 2 m by 1.2 m. Individual blocks were spaced1 m apart while the plots within the blocks separated by 0.5m.

The seeds were planted directly and plots prepared to a fine tilth at a spacing of 30cm x 10cm. Experimental plots were 42 each having 45 plants.

The plants were subjected to treatments after two weeks of germination in the plots. This was applied through drenching in the soil at the rate of 20 ml per plant, Farm yard manure applied once during planting at the rate of 200g per hole, Diammonium phosphate and Lime were applied once at planting at a recommended rate of 5g per plant and 130g respectively.

Management of the Experiment

Land preparation was done one month before sowing by clearing the weeds followed by ploughing. The field was harrowed to create a suitable tilth. Seeds were planted at a depth of 2 mm in the raised plots. Routine field maintenance practices such as weeding, watering were done and also spraying against pests and fungal diseases when necessary using recommended pesticides and fungicides respectively.

Data Collection

The data were collected per individual plot for the 8 sampled plants per plot and were dried. This was done after 10 weeks from planting.

Sample preparation and analysis

Effect of Leaves Extract on Soil pH

Soil samples for pH were taken from the experiment site and using 1:2 ratio, Soil to Water, from a depth of 0-20 and 20-40cm. The samples were air-dried and ground to pass through a 2mm sieve and analyzed for pH according to (Miller and Kissel, 2010).

Effects of Leaves Extracts on Betacorotene Levels

The amaranthus leaves were harvested at intervals of one week and betacarotene was extracted.Determination of Beta-carotene was by carotene equivalent using acetone as solvent, by AOAC method (AOAC, 1995). The concentration of carotene was read directly from UV visible spectrophotometer at 440nm after proper calibration of the instrument with standard solutions of pure beta-carotene (Sigma chemical Co., St. Louis, and Mo).

Statistical Analysis

All the plant biochemical data were subjected to analysis of variance (ANOVA) using the General Linear Model. Proc GLM code of SAS- computer software (SAS 2002; Version 16.0) where significant, mean separation were done with LSD.

Results and Discussion

Effects on the soil pH

The pH changes with various treatment are given in Table 1. the pH under green house regiment ranged from--5.604 to 6.233 with inorganic soil having the lowest pH , while under irrigation regime the pH ranged from 5.53 to 6.172with inorganic soil having the lowest and *Plectranthuus barbatus* the highest. Rainy regime the pH ranged from 5.5 to 6.1 with lime having the highest and inorganic soil the least.

Significant differences ($P \leq 0.05$) were observed between the treatments under all the three regimes(Table i)

There was no significant difference in the two varieties.

Analysis of variance for soil pH indicated significant ($p<0.05$) differences among the treatments with leaf extract *plectranthus barbatus* having highest effect (5.9 to 6.7) for the two varieties. However the inorganic fertilizer had the lowest effect. (5.9 to 5.3) as shown in (Figure 1). It is important to note the pH of control and inorganic remained below 6 in the three regimes while that of the the leaf extract remained above six in the three regime and *Plectrathus barbatus* and *Tithonia increased* betacorotene levels substacially in amaranthus compared to inorganic fertilizers.

Effect on betacarotene

From Table ii and figure 2 Under rainy season, FYM had the highest effect (44.87) while control (21.77) had the lowest.

On irrigation, leaf extract 3 had the highest effect (36.87) and control had the lowest effect (18.77).

On greenhouse, FYM and leaf extract 3 had the highest effect (52.36 and 47.32) and control (27.32) had the lowest. (Figure 2)

It is important to note that under various regimes , inorganic fertilizer had the lowest beta carotene compared to leaf extract and lime. Its levels were only higher than that of the control.

Tables And Figures

Table i; Effect of Treatments on the Soil pH under the Three Regimes

Treatment	Greenhouse	Irrigation	Rainy
CONTROL	5.962e	5.947c	5.956d
FARM YARD MANURE	6.031d	5.964c	5.973cd
INORGANIC FERTILIZER	5.604f	5.53d	5.555e
LEAF EXTRACT 1-TITHONIA	6.068cd	6.023b	6.018bc
LEAF EXTRACT 2-VITEX KENIESIS	6.096c	6.028b	6.046b
LEAF EXTRACT 3-PLECTRAS BARBATUS	6.233a	6.172a	6.148a
LIME	6.183b	6.153a	6.153a
LSD	0.03894	0.02864	0.04953
CV(%)	0.80	0.60	1.00

Treatments with different letters in the same column are significantly different at 5% probability

Table ii:ANOVA on the Effect of Treatment on Betacarotene on Variety Under Combined Regime

Table ii Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	3.13	1.56	1.77	
Regime	2	1413.41	706.71	799.5	<.001signf.
Variety	1	2.26	2.26	2.56	0.114
Treatment	6	7315.99	1219.33	1379.4	<.001signf.
Regime.Variety	2	0.44	0.22	0.25	0.778
Regime.Treatment	12	162.56	13.55	15.33	<.001signf.
Variety.Treatment	6	6.64	1.11	1.25	0.289
Regime.Variety.Treatment	12	12.05	1.00	1.14	0.343
Residual	82	72.48	0.88		
Total	125	8988.97			

Table: iii Effect of Treatment on Betacarotene on the Regimes.

Treatment	Greenhouse	Irrigation	Rainy
CONTROL	26.67l	19.22o	21.89n
FARM YARD MANURE	51.51a	38.36e	45.02o
INORGANIC FERTILIZER	30.47j	23.64m	24.47m
LEAF EXTRACT 1-TITHONIA	41.82d	33.49h	37.82ef
LEAF EXTRACT 2-VITEX	37.17f	31.67i	34.5h
LEAF EXTRACT 3-PLECTRAS BARBATUS	46.14b	35.98g	41.98d
LIME	32i	26.13l	28.13k
LSD	1.08		
CV(%)	2.8		

Treatments with different letters in the same column are significantly different at 5% probability

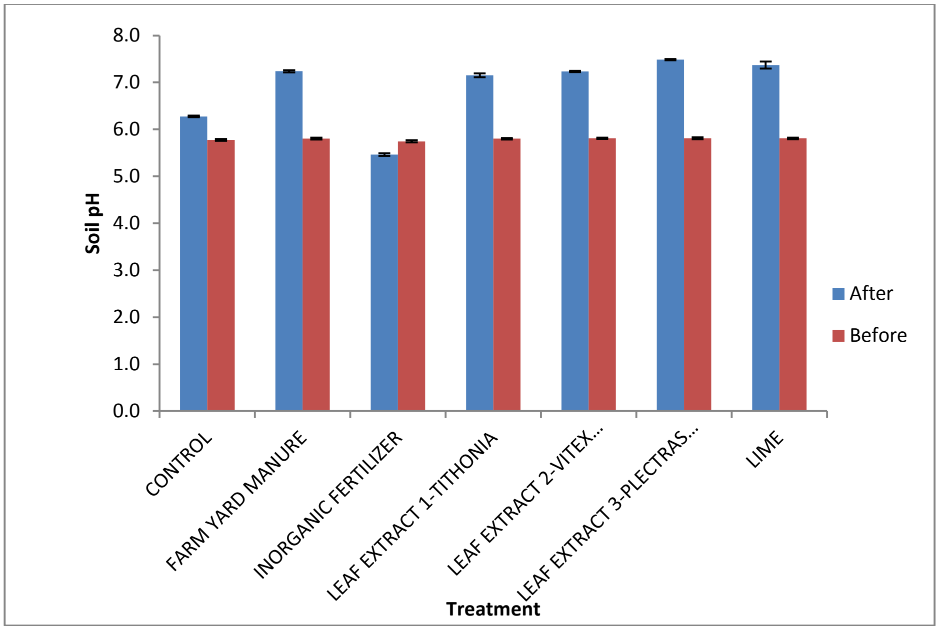

Figure 1: Effect of the Treatments on the Soil pH

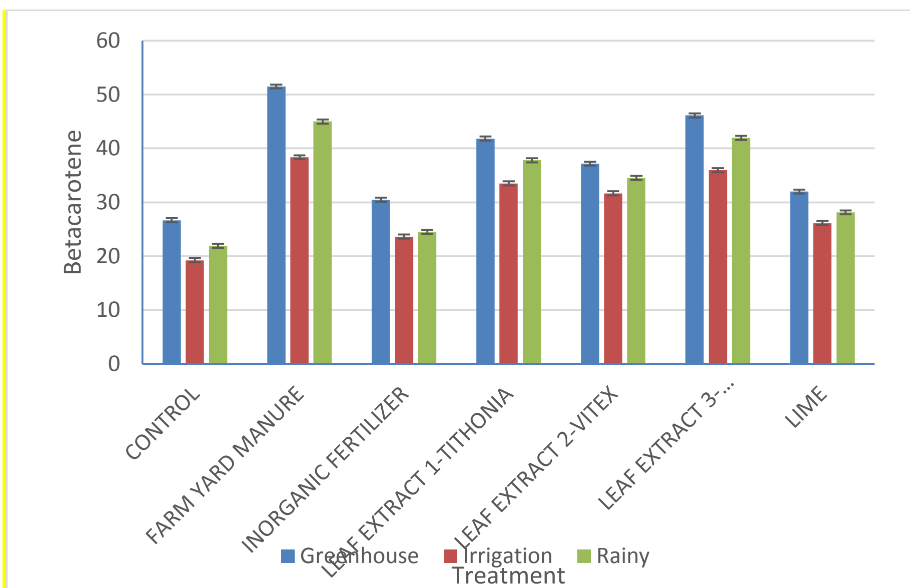

Figure 2: Comparison of Betacarotene Levels among Regimes and Treatments

CONCLUSIONS AND RECOMMENDATIONS

Significant differences (P≤0.05) were observed between the treatments under all the three regimes. This was important as buffering of the soil, in making the soil pH rise and in maintaining it to enable the growth of the amaranthus. This was observed in the greenhouse unlike in the rainy season as some of the soils were leached. Leaf extract3, had the highest effect in the three regimes and control the lowest effect. (Table i)
There was no significant difference in the two varieties.

The soil pH indicated significant ($p<0.05$) differences among the treatments with leaf extract 3, *Plectranthus barbatus* highest effect, under irrigation.

The inorganic fertilizer decreased the soil pH.FYM and *Plectranthus barbatus* had the highest effect on betacarotene levels.(Table ii & iii)

More research is needed to evaluate the effect of the leaf extracts over a longer period of time on the soil pH, and also growing other different vegetables especially those with betacarotene to check their levels.

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6. Parallel Session 5: Agricultural Innovations, Intensifications and Risk Management

6.1 Farmer knowledge and utilization of rainwater harvesting and conservation technologies in a semi-arid agro-ecozone of kenya

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ABSTRACT

Food insecurity is a major problem facing farming communities in the semi-arid zones of Tharaka Nithi County in the Eastern parts of Kenya. Recurrent drought, inter-seasonal dry spells and soil fertility challenges are key causes of food insecurity, particularly within the smallholder farming sector in Kenyas' semi-arid lands. Rain water harvesting and technologies are important strategies to enhance water use and food productivity, however factors affecting utilisation of these technologies by farmers have not been well understood. Therefore this study was conducted in Tharaka South sub-county to establish the relationship between knowledge levels of rain water harvesting and conservation technologies by farmers and technology utilization. Farm and social data was collected using interviews from a total of 353 household heads. Farmers knowledge scores for less knowledge intensive technologies was higher compared to more knowledge intensive technologies, indicating the need for more focused training to enhance knowledge of all rain water harvesting and conservation technologies. The study concluded that farmer socio-economic characteristics were important factors which should be considered in future approaches to develop and disseminate rain water harvesting and conservation technologies in Tharaka sub-county. This study fills an important gap by providing recommendations on increasing productivity and sustainable management of soil and water resources for improved food security by extension officers, government policy makers and smallholder farmers in the semi-arid lands.

Key words*:* Soil and water conservation, climate change, agriculture, green water stress, local knowledge

INTRODUCTION

Rain water harvesting and conservation technologies are important technologies necessary to enhance agricultural production in the semi-arid agro-ecosystems of Kenya which depend on rain-fed agriculture. Several bio-physical studies in Africa have shown the potential of rain water harvesting and conservation technologies to enhance agricultural productivity. The potential of RWH in providing supplementary water, increase crop yield and reduce the risk of crop failure is high (Critchley and Siegert, 1991). In Kenya, studies and development work around rain water harvesting and conservation technologies have been undertaken for more than 50 years in semi-arid agroecological zones (Tiffen et al., 1994), however these technologies have not been widely adopted by farmers.

Rain water harvesting techniques can be classified into two major types depending on source of water collected; namely, the in situ and the ex situ types of rainwater harvesting, respectively. In essence, in-situ rainwater harvesting technologies are soil management strategies that enhance rainfall infiltration and reduce surface runoff. Different rain-water harvesting and conservation technologies can also be classified depending on their intensive levels of knowledge or resource requirements during their installation and maintenance.

Lack of knowledge and awareness coupled with several socio-economic characteristics is a key factor which can explain low adoption rates of rain water harvesting and conservation technologies.

It is important to establish causes of low adoption in light of challenges such as food insecurity, water scarcity and limited fertile land (Wildemeersch et al., 2013). Critchley (2009) discussed the importance of agricultural extension and the role of farmer knowledge and farmer-to-farmer extension in rain water harvesting adoption, underlining the important role of capacity building in uptake. Hassan and Nhemachena (2008) show that in Africa, 50% of farmers believe that temperatures are increasing and precipitation is becoming less, but only 20% of the respondents believe that soil and water conservation could help them adapt, showing the existence of knowledge gaps regarding rain water harvesting and conservation technologies among farmers.

Various water harvesting and conservation technologies have been successfully tested and popularized by governmental and non-governmental agencies (Pachpute, 2010). Few of these efforts have succeeded in combining technical efficiency with social acceptability to local farmers (Pachpute, 2010). Consequently, rainwater harvesting has not been practiced to the recommended levels hence the continued crop failure leading to food insecurity (Kahinda & Taigbenu, 2011). It is of paramount importance to learn about the available rainwater harvesting and conservation technologies, and the socio-economic characteristics influencing their use and non-utilisation. Several studies on agricultural innovations including rain water harvesting technologies have shown that farmers in Sub-Saharan Africa are knowledgeable about their ecological agro-ecological settings, but the knowledge on specific soil water conservation technologies is variable which influences adoption and utilization of rain water harvesting and conservation technologies. There is lack of scientific knowledge on the adoption, utilisation behaviour, and farmer knowledge and perception of recently introduced rain water harvesting and conservation technologies in Kenya hence the gist of the current study. Most studies on rain water harvesting and conservation technologies have been based on the biophysical aspects of the technologies with a minimal focus on farmer perspectives, knowledge and experience with these technologies. Helmreich and Horn (2009) indicated that local skills and resources are key inputs for rain water harvesting and conservation technology development. The aim of the study was to examine farmer knowledge and experience with various rain-water harvesting and conservation technologies using scientific scaling criteria developed to verify farmer knowledge systems. The study also aims to investigate the relationships between knowledge of different types of rain-water harvesting and conservation technologies to determine patterns in rain-water harvesting knowledge and farmer typologies. The study proposes that farmer knowledge and experience with the technologies is an important entry-point for the development and sustainable adoption and utilisation of rain-water harvesting and conservation technologies in low-input, low-output water limiting agricultural systems in semi-arid zones of Eastern Kenya.

MATERIALS AND METHODS

Study Area

The study was carried out in Tharaka South Sub-County in Tharaka Constituency, Tharaka Nithi County. The constituency covers an area of 1,569.5 km^2 with 175,905 people as per the 2009 population census of Kenya (Republic of Kenya, 2010). Tunyai and Nkarini locations were sampled for the survey. Tharaka South Sub-county has a wide representation of agro-ecological zones (AEZs). These are Lower Midland 4 (LM 4), Lower Midland 5 (LM 5), Intermediate Lowland Zone 5(IL 5) and Intermediate Lowland Zone 6 (IL 6) (Smucker & Wisner, 2008).

The study area was mainly in the Lower Midland 4 (LM 4) and the Lower Midland 5 (LM 5) (Icheria, 2015) zones. Figure 1 represents the study area.

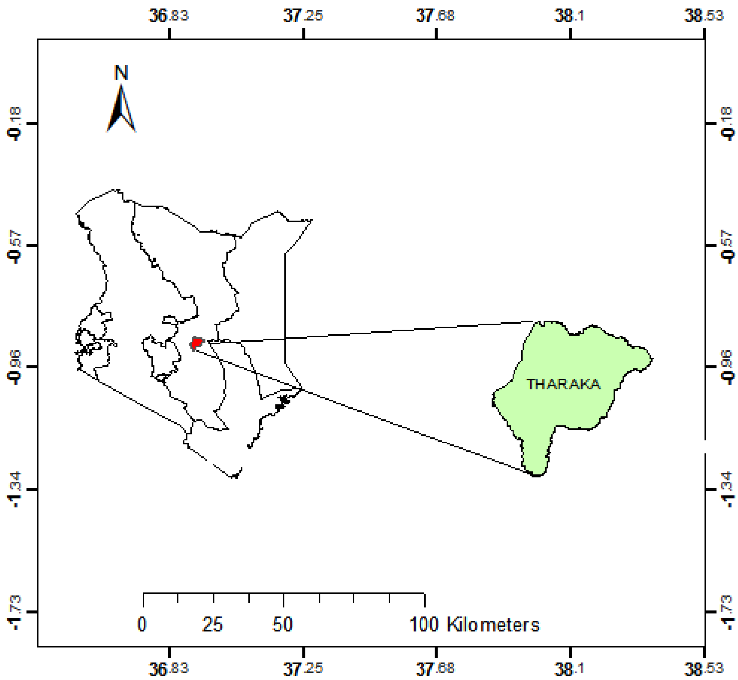

Figure 1: Map of the study area

Tharaka South Sub County is located on the Eastern side of Mount Kenya, and experiences a bi-modal rainfall pattern: the long rains are experienced in the months of March and May each year, while the short rains occur between October and December. A large segment of the population in Eastern Kenya depends on the short rain season which is considered to be more reliable and can be predicted with a reasonable degree of accuracy (Recha *et al.*, 2012). Rainfall is unevenly distributed within these rainy seasons and shows significant variability from year-to-year and season-to-season (Cooper *et al.*, 2008). The total bimodal rainfall averages between 200mm and 800mm annually with its temperature ranging from 11^0 C to 25.9^0 C during cold and hot seasons respectively (Jaetzold *et al.*, 2006).

The soils in Tharaka South Sub-county are predominantly sandy loam and shallow hence the March- May rainfall which is little may not buffer crops from agricultural drought (Recha *et al.*, 2012). Crops grown in the area include Sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), cowpea (*Vigna unguiculata*) and green grams (*Vigna radiata*). These four crops are adapted to drought and form the basis of Tharaka cropping systems. Maize (*Zea mays*) and pigeon pea (*Cajanus cajan*), pumpkins (*Cucurbita sp*.), cotton (*Gossypium sp*.), beans (*Phaseolus sp*.), cassava (*Manihot esculenta*), and dolichos (*Dolichos sp*.) are also grown in the study area (Labeyrie *et al.*, 2014).

Survey sampling procedure

The study adapted a survey design, where surveys and interviews were used to gather data from farmers and informants. Using information from the local administration and Ministry of Agriculture extension staff and local leaders, a list of household heads was generated. Sample size was calculated using formulae 1 (CRS, 2007) resulting in a sample size of 351 farmers.

$$S = \frac{Z^2 * (p) * (1-p)}{c^2}$$

Where: S=Sample size, Z=Z value (e.g. 1.96 for 95% confidence level), p=percentage of picking a choice, expressed as decimal (0.5), c=confidence interval, expressed as a decimal (0.5±5%).

Two locations, Nkarini and Tunyai were sampled. The households were clustered into sub-locations. The number of households to be interviewed per sub location in each location was identified through proportionate sampling method after the total sample size was determined. The households were arrived at through systematic random sampling where every 10^{th} household head was interviewed.

Data collection and analysis

Semi-structured questionnaires were used to collect data from sampled farm households. Frequencies and descriptive statistics were used to summarise the data, while cross-tabulations were used to display relationships in the data.

Scores for each rainwater harvesting and conservation technology were added to calculate knowledge scores for each farmer interviewed after which they were used for data analysis (Nampanya *et al.*, 2010). The scoring was implemented using a marking scheme on a 3-point scale, with 3 marks for correctly answered questions, 2 (partly correct), and 1 mark (wrongly answered). Different key questions were asked for the different technologies, meant to gauge the basic knowledge for the respective technologies in relation to physical structures of the technologies and their application to agriculture and soil/water conservation. Comparison of mean score was carried out for each rainwater harvesting and conservation technology between farmers utilizing the technology and those who were not utilizing the technology using analysis of variance (ANOVA). Correlation co-efficients were used to relate household characteristics and knowledge mean scores.

RESULTS AND DISCUSSIONS

Farmer socio-demographic characteristics

Table 1 describes the socio-economic characteristics of farmers in Tharaka South Sub-county. Male-headed households consisted of 80% of the sample, while female-headed households comprised 20% of the total sample size of 353 households. The age distribution showed that household heads in the 21-36 year age-cohort were 27%, while those in the 37-52 groups were 36% of the total sample.

Farmers who were over 69 years consisted of only 7.4% (Table 1).

Table 1: Socio-economic characteristics of the household heads in Tharaka South Sub-county

Variable	Categories	Frequency	Percent
Gender of household head	Male	283	80.2
	Female	70	19.8
Age household head	21-36	91	27.1
	37-52	120	35.7
	53-68	100	29.8
	Over 69	25	7.4
Marital status of household head	Single	57	16.2
	Married	295	83.8
Education level of household head	None	99	28.0
	Primary	161	45.6
	Secondary	69	19.5
	College	18	5.1
	University	6	1.7
Main occupation of household head	Full time farmer	261	74.1
	Casual laborer	15	4.3
	Business	52	14.8
	Formal employment	24	6.8
Group membership status	Non-group members	253	71.7
	Group members	100	28.3
Labour source	Family labour	233	66.0
	Hired labour	120	34.0
Title deed ownership	Holds no title deed	161	45.6
	Holds title deed	192	54.4
Credit access	With no access to credit	242	68.6
	With access to credit	111	31.4

Married households' heads consisted 84%, while up to 72% of the household heads had achieved education beyond primary school (Table 1). Most of the household heads were full time farmers (74%), while 72% of the farmers did not belong to a farmers group. Most of the farm labour was family based (66%), while hired labour was used by 34% of the farms (Table 4.1). Up to 54% of the farmers held a title deed, while only 31% of the farmers had access to credit (Table 1).

The study indicates that most of the farmers were younger than 52 years. This age set is important in manpower and experience provision for labour and knowledge- intensive technologies (physical soil structures) such as Fanya juu, Negarim pits and Zai pits which may demand substantial installation and maintenance labour input especially when this labour is household derived. Most of the farmers were educated to the secondary school level, which is beneficial for rain-water harvesting technology

development and utilisation especially for knowledge intensive technologies, including the recently introduced technologies which may not be well understood in the farming system.
Ample farm households were members in groups (28%) indicating the potential to disseminate and utilise technologies because these technologies can be more efficiently disseminated in group frameworks with potential synergistic social benefits especially if group dynamics are effectively managed. Given that most of the respondents were full-time farmers, with title deeds with formal education, and with sufficient family labour, the social setting is generally viable to introduce, develop, and disseminate rainwater harvesting technologies in a more cost-effective and socially acceptable manner among the farmers in Tharaka sub County. However, the low level of access to credit by most of the farmers (less than 31%) could be an impediment to dissemination of technologies, especially those that are resource intensive in terms of their installation and maintenance. In resource-limited households, less resource-intensive technologies especially biological technologies such as grass strips, may be suitable technology options especially when soil, terrain, and climatic characteristics are favourable for the installation of these technologies.

Household size averaged 5 members, while household members involved in day to day activities consisted of 3 members (Table 2). Years of farming experience ranged from 1-57 years, with an average of 18 years. Farm size ranged from 0.1 ha to 18 ha (mean =2.3 ha) while land under crops was 1.5 ha. Land under pasture averaged 0.8 ha while fallow land averaged 0.4 ha.

Land areas under dry-season irrigation and permanent irrigation ranged between 0-8.1 ha averaging 0.2 ha (Table 2).

Table 1: Household and farm characteristics of small-holder farmers in Tharaka-Sub-County

Parameter	N	Minimum	Maximum	Mean	Std.Dev
Household size	353	1.0	11.0	4.9	1.94
Household members involved in day to day farming	338	1.0	10.0	2.9	1.78
Years of farming	340	1.0	57.0	17.6	13.62
Farm size (ha)	353	0.1	18.2	2.3	2.50
Land under crops (ha)	350	0.0	8.9	1.5	1.10
Land under pasture (ha)	323	0.0	14.2	0.8	1.70
Land under fallow (ha)	301	0.0	6.1	0.4	0.80
Land under continuous irrigation (ha)	301	0.0	8.1	0.2	0.60
Land under dry spell irrigation (ha)	297	0.0	8.1	0.2	0.60

The number of household members involved in active running of the farm would have an influence on the rainwater harvesting and conservation technology utilized. This is because the technologies vary in their labour requirement. Households with more individuals available to contribute farm labour are likely to install and utilize labour intensive technologies for instance *zai* pits and fanya juu terraces. Some of the technologies are highly dependent on the farm size. Technologies that lay a demand on the cultivated land for instance the use of grass strip may not be favourable among farmers with smaller sizes of cultivated land. Additionally larger total land size is an important factor in utilization of technologies such as stone terraces which require expansive piece of land for stones collection.

Linkages between socio-economic characteristics and knowledge

Knowledge questions connected to rain water harvesting and conservation technologies were focused on technical design and their application in agriculture and soil/water conservation. The knowledge mean scores were highest for trashlines (1.7), followed by stone terraces (1.4), grass strips (0.9), Zai pits (0.9) and Negarim pits (0.7) (Table 3). These scores indicate that farmers had higher knowledge levels for less knowledge intensive and traditional soil technologies compared to more advanced soil structures.

Table 3: Mean knowledge scores among farmers in Tharaka sub-county

Technology	Mean	N	Std. Deviation
Trash lines	1.71	344	0.4
Stone terraces	1.40	305	0.56
Grass strips	0.90	343	0.85
Zai pits	0.88	344	0.82
Negarim pits	0.67	240	0.73

Knowledge mean scores were significantly higher among technology users in all technologies than among farmers who did not utilize the rainwater harvesting and conservation technologies (Table 4). The mean difference tended to be highest in *Negarim* pits and *Zai* pit scores compared to other technologies that were utilized by farmers (Table 4). There were no significant differences in mean scoring by education and marital status. Gender influenced significantly *Zai* pits and stone terrace technology scoring.

In addition, the age category significantly affected the knowledge score for Trashlines and *Zai* pits (Table 4).

Table 4: Knowledge mean scores conditioned by socio-economic characteristics of household heads in Tharaka South Sub-county

Parameter	Trashlines	*Zai* pits	*Negarim* micro-catchments	Stone terraces	Strip catchment tillage
Utilization of technology					
No	1.6(91)	0.7(250)	0.6(199)	1.2(152)	0.8(273)
Yes	1.8(248)	1.4(85)	1.4(34)	1.5(149)	1.4(62)
Sig.	*0.029*	*0.000*	*0.000*	*0.000*	*0.000*
Education level					
None	1.8 (94)	0.9 (94)	0.7 (70)	1.5 (85)	0.9 (94)
Primary	1.7 (160)	0.8 (160)	0.6 (103)	1.3 (140)	0.8 (160)
Secondary	1.7 (67)	0.9 (67)	0.7 (50)	1.5 (61)	1.1 (67)
College	1.7 (18)	0.9 (18)	0.7 (13)	1.2 (14)	0.9 (17)
University	1.8 (5)	0.9 (5)	0.8 (4)	1.1 (5)	0.8 (5)
Sig.	*0.311*	*0.83*	*0.862*	*0.129*	*0.208*
Marital status					
Single	1.7 (56)	0.9 (56)	0.7 (41)	1.4 (49)	1 (56)
Married	1.7 (287)	0.9 (287)	0.7 (198)	1.4 (255)	0.9 (286)
Sig.	*0.608*	*0.562*	*0.639*	*0.846*	*0.391*
Gender					
Male	1.7 (275)	0.8 (275)	0.7 (189)	1.4 (244)	0.9 (274)
Female	1.7 (69)	1.1 (69)	0.7 (51)	1.2 (61)	1 (69)

Sig.	*0.508*	*0.033*	*0.657*	*0.017*	*0.637*
Age category					
21-36	1.6 (88)	0.6 (88)	0.6 (62)	1.3 (77)	0.8 (88)
37-52	1.7 (117)	1 (117)	0.7 (77)	1.5 (101)	1 (117)
53-68	1.8 (98)	1 (98)	0.7 (74)	1.4 (88)	0.9 (97)
Over 69	1.5 (24)	1 (24)	0.6 (18)	1.3 (24)	1.1 (24)
Sig.	0.008	0.014	0.688	0.115	0.473
Mean score	1.7 (344)	0.9 (344)	0.7 (240)	1.4 (305)	0.9 (343)

Values in parentheses are number of farmers

Knowledge mean scores were significantly associated with utilization categories, whereby farmers with knowledge recorded significantly higher scores in all technologies. This finding collaborates well with the influence of training in most of the technologies in earlier results elsewhere.

Rainwater harvesting and conservation technologies comprise a major contributor to the measures that the water sector in Africa needs to undertake to cope with future climate change (Kahinda *et al.*, 2010). Farmers armed with new knowledge and skills are better placed to make informed decisions that pertain to improved technologies in managing their resources for improved livelihoods (Wegulo *et al.*, 2009).

Education and land size were positively and significantly correlated with knowledge levels while age was negatively correlated (Singha & Devi, 2013). This study agrees with the current where farm size is positively correlated to the knowledge on all the rainwater harvesting and conservation technologies with significance found in relation to *Zai* pits technology. In reference to age, knowledge level on *Zai* pits recorded a significant positive correlation with age contrary to the findings in (Singha & Devi, 2013).

This study found out that knowledge mean scores were significantly higher among farmers utilizing the rainwater harvesting and conservation technologies as compared to the farmers who did not utilize the rainwater harvesting and conservation technologies. According to Amsalu & Graaff (2006) in a study carried out in Ethiopia; farmers' decisions pertaining to soil water conservation were largely determined by their knowledge of the problem and the perceived benefits from conservation. The soil and water conservation measures included, stone terraces/bunds, soil bunds, waterways, grass strips, contour terraces and tree planting herein referred to as rainwater harvesting and conservation technologies.

Gender influenced the knowledge level on specific rain water harvesting and conservation technologies. This was exemplified in the score for *Zai* pits where females were more knowledgeable than the male gender and Stone terraces where the male gender scores were significantly higher than the female gender ($p<0.05$). In determining the traditional ecological knowledge among the Turkana of Kenya, the variation in ethnobotanical knowledge among the respondents was not explained by their age and gender (Stave *et al.*, 2006). This is partly in agreement with the current study where age category did not explain the knowledge mean score among the respondents while gender significantly influenced the knowledge score.

All technology scores were positively and significantly associated, implying that knowledge of one technology was associated with another (Table 5). Years of farming experience, Age and farm size was linked significantly to scoring on *Zai* technologies. Years of farming experience was also positively associated with the knowledge scored in regard to *negarim* micro-catchments, stone terraces and strip catchments.

Table 5:Correlation co-efficient between technology knowledge scores and farm characteristics in Tharaka South sub-county

Parameters	1	2	3	4	5	6	7	8	9	10	11	12
Trashline score (1)	1											
Zai pits score (2)	0.26**	1										
Negarim score (3)	0.13*	0.53**	1									
Stone terrace score (4)	0.46**	0.30**	0.34**	1								
Strip catchment score (5)	0.30**	0.52**	0.47**	0.32**	1							
Years of farming (6)	0.08	0.18**	0.15*	0.14*	0.11*	1						
Age (7)	0.05	0.14*	0.01	0.06	0.02	0.57**	1					
Farm size (8)	0.05	0.11*	0.10	0.03	0.10	0.31**	0.36**	1				
Crop area (9)	0.09	0.04	-0.03	0.01	-0.04	0.20**	0.26**	0.59**	1			
Household size (10)	0.04	0.07	0.06	0.01	-0.08	0.16**	0.20**	0.14*	0.12*	1		
Irrigated land(continuous) (11)	0.01	-0.05	0.01	0.04	-0.02	0.09	0.08	0.23**	0.53**	0.01	1	
Irrigated land(dry) (12)	0.08	-0.00	0.03	0.11	0.06	0.08	0.05	0.30**	0.54**	-0.01	0.91**	1

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

The knowledge of one type of technology was associated with the knowledge score of other technologies which is expected, because the basic principles behind all of the technologies is almost similar and based on water and soil conservation principles. Negarim pit and Zai pit scores were highly associated possibly because these technologies are both structurally similar in some aspects-based on basins, and being that they are newly introduced in the area. From the findings of this study, it can be concluded that farmers gain experience over time and adapt better to the risks involved in their production activities hence over time they are likely to embrace rainwater harvesting and conservation technologies.

This is deduced from the positive association between years of farming experience and the knowledge mean score on most of the rainwater harvesting and conservation technologies investigated. Mulumba *et al.* (2012) reported diversity of knowledge on farm management among smallholder farmers in Uganda. This position is supported by various researchers including Mango (2002); Joshi *et al.* (2005) and Kiptot (2007) who asserted that knowledge evolve over time as the technology adapts to the unique circumstances of a location.

Interdependent relationships in farmer knowledge

A Factor analysis of scores of 6 rainwater harvesting technologies revealed 3 factors describing farmer rating patterns of the technologies, explaining 67% of the total variance in farmer perception. The first factor of types of technologies that were closely associated in their scoring matrices due to the high loading (correlation) values with component 1 included *Negarim* pits (0.783) and grass strips (0.815). There was a second distinct set of farmers who rated stone terraces and trash lines similarly (component 2). This group of farmers tended to rate technologies in component 1 and component 3 differently. *Fanya juu* and Zai scores formed a third distinct set of farmer rating pattern. All scored parameters were relevant and contributed sufficiently to the model as represented by the magnitude of their communalities (Table 6).

Table 6: Rotated 3-factor model of farmer scoring of rain water harvesting technologies

	Component			
Technology	1	2	3	Communalities
Grass strips	0.815			0.715
Negarim pits	0.783			0.691
Stone terrace		0.784		0.644
Trash lines		0.731		0.545
Fanya juu terraces			0.862	0.787
Zai pits			0.613	0.680
Eigen values	**2.0**	**1.1**	**1.0**	
Variance %	**33.2**	**18.9**	**15.6**	
Cumulative variance	**33.2**	**52.1**	**67.7**	

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Cut point for loading extraction= 0.5

The multivariate analysis indicated underlying contrasts in the utilization and perception of the technologies by farmers. Farmer scoring of technologies was based on their specific experiences with the technologies, and as a result the scoring matrix could not have arisen by chance but rather indicates farmer typologies and underlying processes in relation to various technologies that were utilized and rated.

The 3 components indicated different types or clusters of farmers in relation to the technologies due to correlation scoring matrices associated with the technologies which could have resulted from different socio-economic and biophysical circumstances of the farmers. For example, stone-line and trashline component scorers indicated that these farmers predominantly used these technologies in association more than with other technologies, hence tended to assign similar rating patterns to these technologies. This finding was expected because these technologies are likely to be used in similar climatic, soil, and socio-economic settings than with other technology sets or combinations of technologies.

CONCLUSIONS AND RECOMMENDATIONS

Farmer scores of different technologies indicated that farmers scored highly in less knowledge intensive technologies such as grass strips compared to more knowledge-intensive technologies such as Zai pits. Overall scores indicated that farmers had a below average to average understanding of rain water harvesting and conservation technologies in terms of their technical aspects, design and application in soil water conservation.

The knowledge of one type of technology was associated with the knowledge score of other technologies which was expected. Multivariate analysis showed underlying contrasts in the utilization and perception of the technologies by farmers. The factor analysis revealed 3 types of farmers in regard to technology utilization which could have resulted from different socio-economic and biophysical circumstances. These types of farmers could be strategically targeted in interventions to develop technologies in the study area, including group formation, resource allocation, training and dissemination.

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6.2 Efficacy of Selected Crude Plant Extracts on Post-Harvest Pathogens in Tomato Fruits in Kirinyaga County, Kenya

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ABSTRACT

Post-harvest diseases of tomato fruits pose a very big challenge in the food chain worldwide. Several types of synthetic chemicals have previously been used to control post-harvest decay of fruits but there is increasing consumer concern over pesticide residues on foods. Pesticides are known to be toxic, carcinogenic and cause environmental pollution. In this study, three different crude plant extracts (ginger, neem and garlic) were evaluated *in vitro* and *in vivo* at different concentrations for the control of pathogens causing post-harvest rot of tomato fruits. The concentrations used were: 1mg/ml, 2mg/ml, and 3mg/ml. The pathogen species isolate from tomato and used in this study were *Fusarium, Rhizopus, Geotrichum* and *Erwinia.* Pathogen growth media was amended with the crude extracts and the pathogens introduced into the media. Radial growth of the fungal pathogens was measured at an interval of twenty four hours after the second day for five days and was compared to the control. Colony forming units were counted for the bacterial pathogen and also compared to the control. To evaluate the efficacy of the extracts, fresh healthy tomato fruits were treated by dipping them in the crude extracts (3mg/ml of each of the extract). Disease development was evaluated and compared to the control. Results obtained showed that all extracts' concentrations inhibited the test pathogens but the inhibitory effect was proportional to the extract concentration. Garlic extract at all concentrations was more effective against all the test pathogens as compared to other extracts. The study also demonstrated that *Fusarium* spp. was more susceptible to the crude extracts as compared to other test pathogens. For *in vivo* evaluation, there was no rot development on the treated tomato fruits but rots appeared in the controls. From the study it is evident that plant extracts can be used as safe alternatives for management of post-harvest rot causing pathogens in tomatoes thus safeguarding the safety of plant, animal and human health and the environment.

Key words: Post-harvest, Plant extracts, Pathogens, Tomato fruit, Inhibition

Significance of the study

This study provides important information on the management of tomato post-harvest losses using crude plant extracts. The outputs of this study will be important in reducing tomato post-harvest losses by improving the efficiency of post-harvest handling due to better post-harvest management strategies.

INTRODUCTION

Tomato is an important commercial vegetable crop in Kenya which is grown both in green houses and open fields. However it is a very perishable fruit crop with a short shelf life and very prone to post-harvest pathogens which cause significant losses on harvested fruits. Different kinds of synthetic fungicides have been successfully used to control the post-harvest decay of fruits and vegetables (Adaskaveg *et al.,* 2004, Kanetis *et al*., 2007). However use of the fungicides has been coupled with major concerns which include: increasing consumer concerns over pesticide residues on foods which may be toxic and carcinogenic; predominance of fungi strains resistant to fungicides due to excessive use of fungicides; and environmental pollution. There is therefore the need to explore safer and effective means of post-harvest disease management that pose less risk to human and animal health and the environment.

Natural products originating from plants and their analogues have been found as important sources of agricultural bio-pesticides which serve as anti-microbial properties of the plant extracts (Cardelina, 1995; Okigbo, 2009). Pesticides from plant origin "referred to as botanicals" are bio-degradable, environmentally friendly, cheap and easy to obtain. According to Arokiyaraj *et al*., (2008), Shanmugavalli *et al*., (2009), Swarnalatha and Reddy (2009), plants are sources of natural pesticides that lead to new pesticide development. Ramazani *etal.,* (2002) reported that chemicals of plant origin are economical, broad spectrum and bio-efficacious. They degrade faster than chemical pesticides, are less likely to destroy beneficial organisms and as such they are considered to be environmental friendly. According to Ilondu *et al*. (2001) some plants contain phenolic compounds and essential oils, which have inhibitory effects on micro-organisms. This study aimed at evaluating the efficacy of selected crude plant extracts (neem plant leaf, ginger rhizome, and garlic bulb) against post-harvest rot causing pathogens (*Fusarium* spp., *Geotrichum* spp., *Rhizopus* spp. and *Erwinia* spp.) in tomato fruits.

MATERIALS AND METHODS

Experimental Design

The experiment was conducted at Kenyatta University, Department of Agricultural Science and Technology Laboratory. The test crude plant extracts were obtained from neem leaves, garlic cloves and ginger rhizomes. The neem leaves were collected from Kenya Agricultural and Livestock Research Organization (KARLO) station in Embu while the ginger rhizomes and garlic bulbs were obtained from Mwea market. The materials were then air dried at Kenyatta University, Department of Agricultural Science and Technology Laboratory. The experimental was laid out as a completely randomized design consisting of four treatments replicated four times. The treatments included: three concentrations of the crude plant extracts (1mg/ml, 2mg/ml and 3mg/ml) dispensed into four petri-dishes and a control.

Preparation of plant crude extracts

The extraction process followed the procedure described by Handa *et al*., (2008). The leaves, peeled garlic cloves and rhizomes were washed under tap water, rinsed three times in sterile distilled water and blotted dry using sterile blotting paper. They were then placed in the oven and dried at a temperature of 40°C for three days. The plant extracts were then ground into powder by use of a sterile mortar and pestle and placed in sterile specimen bottles. This was done to maximize the surface area which in turn enables the mass transfer of active ingredients from the plant material to the solvent.

Fifty (50 gms) of each of the powder were put into separate sterile conical flasks and 150 ml of methanol added ensuring that the powder was completely immersed into the solvent. The mixture was shaken vigorously and allowed to stand at room temperature while shaking it at different intervals for two days. A sterile funnel was placed into a 500 ml conical flask and then a whit man's (No.2) filter paper was folded and placed into the funnel. Some amount of the extract was filtered through a filter paper and the filtrate poured into sterile universal bottles.

The crude extract was concentrated by evaporating the solvent using a vacuum evaporator for 60 minutes at a temperature of 50°C. After evaporation, a spongy like material was obtained which was later dried in an oven at a temperature of 40°C for two days. This generated a powder like substance which was stored in the refrigerator at temperature of 4°C.Different concentrations of the crude extracts were prepared by weighing separately 1mg, 2mg and 3mg of ginger, garlic and neem powder respectively. Each powder was dissolved in 1ml of sterile distilled water to form solutions of different concentrations. One hundrend (100) ml of PDA and NA were amended with 3 ml of each of the different extract concentrations respectively and dispensed into four Petri-dishes and replicated four times. Three (3) ml of water was mixed with the media for the negative controls. The media was allowed to cool and solidify. The bacteria were streaked in each of the amended media and the replicates.

Evaluation of the effectiveness of crude plant extracts on growth of fungal mycelia and

bacterial colonies

The technique of Amadioha and Obi (1999) was used to determine the effectiveness of the crude extracts on the test pathogens. The colony forming units (CFU) were counted after 48 hr. For the fungal treatment, 5mm fungal culture discs from one week old cultures of *Geotrichum* spp., *Fusarium*spp. and *Rhizopus*spp. were cultured at the centre of each Petri-dish per replicate and incubated at room temperature. Measurement of radial growth from each of the treatment was done after the second day and at an interval of 24 hr up to the seventh day. The mean growth of the fungi on the amended media was compared with the control. For the bacteria, colony forming units in different extract treatment were counted.

DATA ANALYSIS

The bio-cidal activity of the plant extracts to the pathogens was analysed using SAS one way ANOVA and Students-Newman-Keuls Test (SNKT $p<0.05$) was used for means separation.

RESULTS

Efficacy of different crude extracts concentrations on radial growth of *Fusarium* spp.

The study revealed that the plant extracts caused radial growth inhibition of *Fusarium* spp. as compared to control but the efficacy varied with concentration (< 0.001). At 1 mg/ml neem, *Fusarium* spp. was completely inhibited (Plate 1). There was slight growth in garlic (5.40 mm) and a mean diameter of 6.4 mm was noted on treatment with ginger (Table1). At 2 mg/ml neem and garlic concentration growth of *Fusarium* spp. was completely inhibited (Plate 1 and plate 3) but there was slight growth in the PDA amended with ginger (Plate 2). At 3gm/ml concentration there was no *Fusarium*growth in all the extracts. There was a significant difference in the effect of different concentrations of ginger on *Fusarium* spp. ($p<0.001$). The effects of different concentrations of garlic also differed significantly ($p=0.012$) (Table 1).

Table 1 Efficacy of crude extracts on radial growth of *Fusarium* spp.

Concentration (mg/ml)	Neem meanRG±SD	Ginger meanRG±SD	Garlic meanRG±SD	p-value
Control	42.85 ± 2.68^{B}	42.85 ± 2.68^{D}	42.85 ± 2.68^{C}	
1	5.00 ± 0.00^{A}	6.40 ± 0.50^{Cb}	5.40 ± 0.82^{Bb}	<0.001
2	5.00 ± 0.00^{A}	5.20 ± 0.41^{Ba}	5.00 ± 0.00^{Aa}	0.012
3	5.00 ± 0.00^{A}	5.00 ± 0.00^{Aa}	5.00 ± 0.00^{Aa}	-
		<0.001	0.012	

Mean values followed by the same lower case within the same column are not significantly different (One way ANOVA, Students-Newman-Keuls test, $\alpha=0.05$) while mean values followed by the same upper case within the same row are not significantly different (One way ANOVA, Students-Newman-Keuls test, $\alpha=0.05$)

RG refers to radial growth and it includes inoculum disc which was 5mm.

Figure 1: Plates showing growth of *Fusarium* spp. on PDA amended with varying concentrations of garlic plant extracts

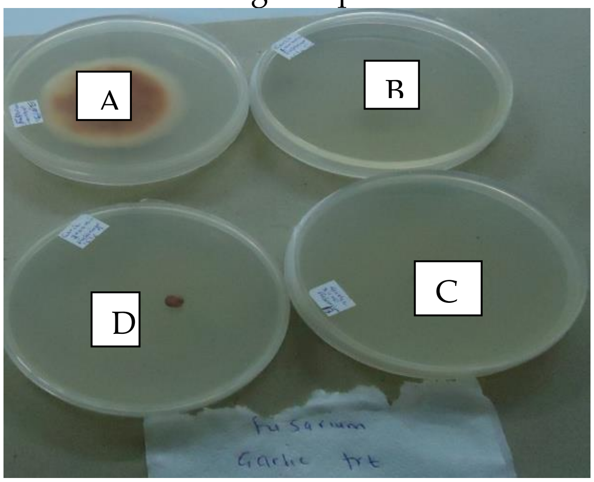


Figure 2: Plates showing growth of *Fusarium* spp. on PDA amended with varying concentrations of ginger plant extracts

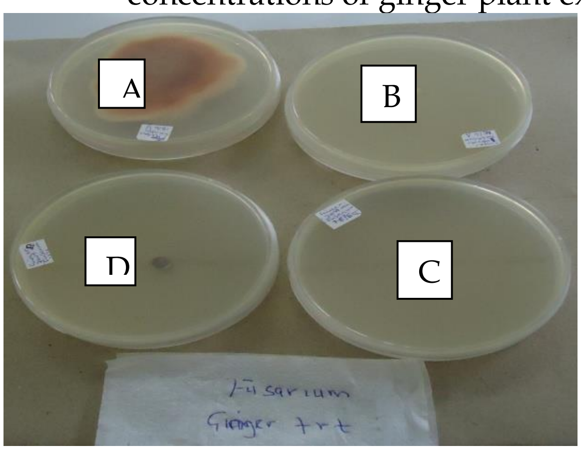
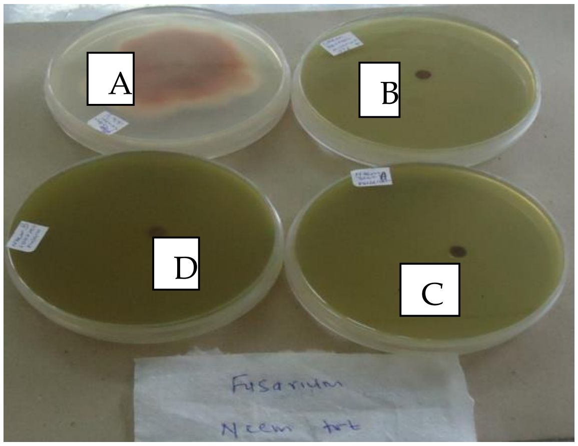


Figure 3: Plates showing growth of *Fusarium* spp. on PDA amended with varying concentrations of neem plant extracts



Efficacy of different crude extracts concentrations on radial growth of *Geotrichum spp.*

Results obtained indicated that the three plant extracts inhibited radial growth on *Geotrichum* spp. as compared to the control but the rate of inhibition varied significantly with different extracts' concentrations ($p<0.001$) (Table 2). At 1 mg/ml concentration, the three plant extracts differed significantly in their effects on *Geotrichum* spp. ($p<0.001$) as indicated in table 2. At the concentration of 2 mg/ml the effects of neem and ginger on *Geotrichum* spp. also differed significantly ($p<0.001$). The most effective concentration in reducing *Geotrichum* spp. radial growth in all extracts was the 3 mg/ml. The effectiveness of neem differed significantly ($p<0.001$) at different concentrations (Plate 5). The effect of ginger also differed significantly ($p<0.001$) at different concentrations and 3 mg/ml concentration was the most effective in reducing the radial growth of *Geotrichum* spp. (Plate 6). Garlic was the most effective in inhibiting growth of *Geotrichum* spp. among the tested extracts (Plate 4).

Table 2 Efficacy of crude extracts on radial growth of *Geotrichum* spp.

Concentration (mg/ml)	Neem meanRG±SD	Ginger meanRG±SD	Garlic meanRG±SD	p-value
Control	34.80 ± 2.42^{d}	34.80 ± 2.42^{c}	34.80 ± 2.42^{B}	
1	7.70 ± 2.08^{Cc}	6.10 ± 1.07^{Bb}	5.00 ± 0.00^{A}	<0.001
2	6.20 ± 1.20^{Cb}	5.60 ± 0.50^{Ba}	5.00 ± 0.00^{A}	<0.001
3	5.00 ± 0.00^{a}	5.00 ± 0.00^{a}	5.00±0.00	-
p-value	<0.001	<0.001	-	

Mean values followed by the same lower case within the same column are not significantly different (One way ANOVA, Students-Newman-Keuls test, $\alpha=0.05$) while mean values followed by the same upper case within the same row are not significantly different (One way ANOVA, Students-Newman-Keuls test, $\alpha=0.05$)

RG refers to radial growth and it includes inoculum disc which was 5mm.

Figure 4: Growth of *Geotrichum* spp. on PDA amended with varying concentrations of garlic crude plant extracts

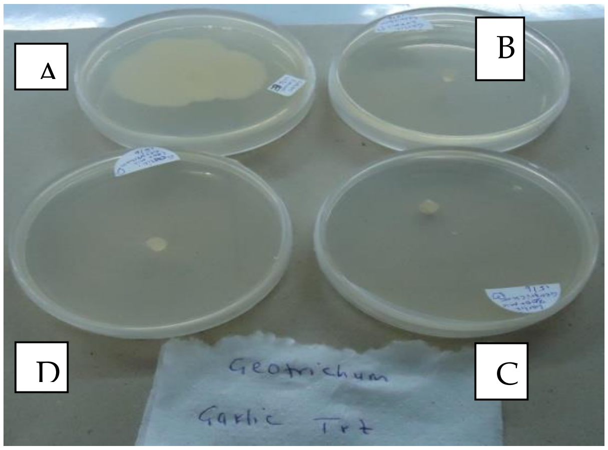


Figure 5: Growth of *Geotrichum* spp. on PDA amended with varying concentrations of neem crude plant extracts

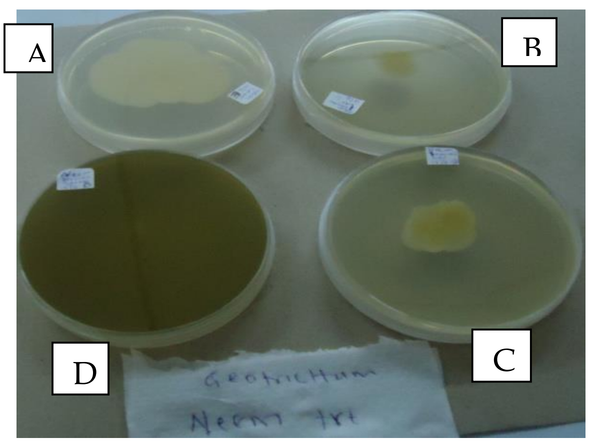
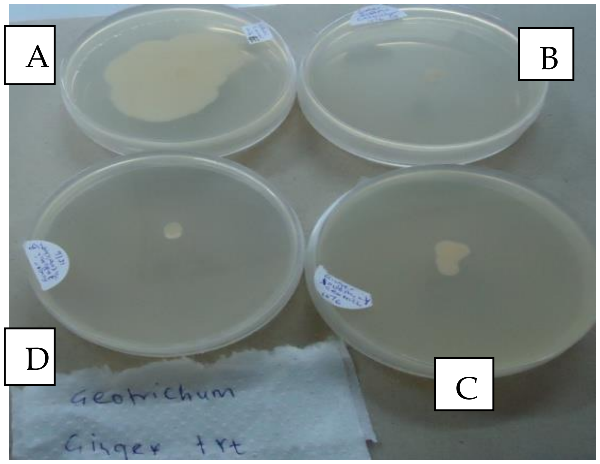


Figure 6: Growth of *Geotrichum* spp. on PDA amended with varying concentrations ginger crude plant extracts



Efficacy of different crude plant extracts concentrations on radial growth of *Rhizopus* spp.

The study revealed that the three plants extracts inhibited radial growth of *Rhizopus* spp. as compared to the control although the rate of inhibition differed significantly with the type of each extract and level of concentration. At 1 mg/ml and 2 mg/ml concentrations, the tested extracts differed significantly (p=0.010) in inhibiting radial growth of *Rhizopus* spp. with garlic proofing to be the most effective extract (Table 3).

At 3 mg/ml concentration radial growth of *Rhizopus* was completely inhibited in all the extracts as shown in plate 7, 8 and 9 for neem, garlic and ginger respectively. The 1 mg/ml and 2 mg/ml concentration did not differ significantly in their effectiveness on *Rhizopus* spp.

Table 3 Efficacy of crude extracts on radial growth of *Rhizopus* spp.

Concentration (mg/ml)	Neem meanRG±SD	Ginger meanRG±SD	Garlic meanRG±SD	p-value
Control	80.15 ± 0.89^{d}	80.15 ± 0.89^{c}	80.15 ± 0.89^{b}	
1	7.20 ± 1.77^{Bc}	6.70 ± 3.57^{Bb}	5.00 ± 0.00^{Aa}	0.010
2	5.85 ± 0.88^{Bb}	5.55 ± 1.15^{Bb}	5.00 ± 0.00^{Aa}	0.007
3	$5.00\pm0.00^{A\,a}$	5.10 ± 0.11^{Aa}	5.00 ± 0.00^{Aa}	0.012
p-value	<0.001	0.028	-	

Mean values followed by the same lower case within the same column are not significantly different (One way ANOVA, Students-Newman-Keuls test, α=0.05) while mean values followed by the same upper case within the same row are not significantly different (One way ANOVA, Students-Newman-Keuls test, α=0.05)

RG refers to radial growth and t includes inoculum disc which was 5mm.

Figure 7: Growth of *Rhizopus* spp. on PDA amended with varying concentrations of ginger crude plant extracts

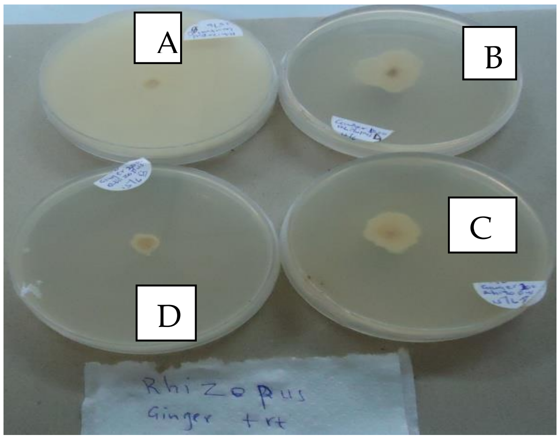


Figure 8: Growth of *Rhizopus* spp. on PDA amended with varying concentrations of neem crude plant extracts

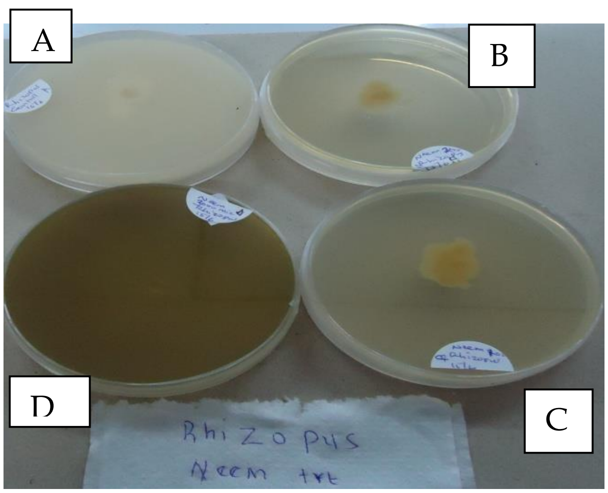
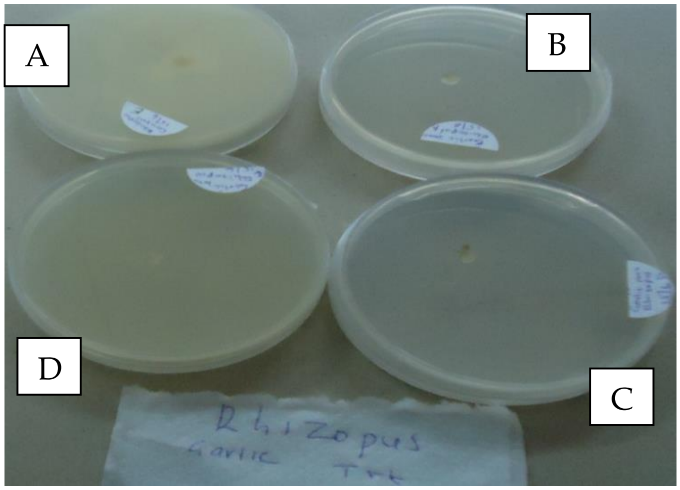


Figure 9: Growth of *Rhizopus* spp. on PDA amended with varying concentrations of garlic crude plant extracts



Efficacy of crude plant extracts on *Erwinia* (*Pectobacterium*)

The study revealed that the number of colony forming units of *Erwinia* spp. on the amended Nutrient Agar (NA) differed significantly ($p<0.001$) in the different concentrations of the tested extracts as compared to the control. At both 1 mg/ml and 2mg/ml, garlic was the most effective extract with least colony forming units followed by neem and ginger respectively (Table 4).

The efficacy of ginger crude extract on growth of *Erwinia* spp. differed significantly ($p<0.001$) at different concentration compared to the control. Three mg/ml was the most effective while the 1 mg/ml was the least effective. The effectiveness of garlic also differed significantly ($p<0.001$) compared to the control. Three mg/ml and 2 mg/ml concentrations had the same effect such that no growth occurred on the amended NA. A few colony forming units were on the NA amended with 1 mg/ml. On evaluation of the three extracts, garlic was the most effective but ginger and neem crude extracts did not differ significantly.

Table 4 Efficacy of crude extracts on the C.F.U of *Erwinia* spp.

Concentration (mg/ml)	Neem Mean±SE	Ginger Mean±SE	Garlic Mean±SE
0	276.25 ± 6.88^{d}	276.25 ± 6.88^{d}	276.25 ± 6.88^{c}
1	89.50 ± 8.77^{c}	105.00 ± 6.45^{c}	28.25 ± 1.65^{b}
2	37.50 ± 4.79^{b}	11.25 ± 1.49^{b}	0.00 ± 0.00^{a}
3	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
p-value	<0.001	<0.001	<0.001

Mean values followed by the same lower case within the same column are not significantly different (One way ANOVA, Students-Newman-Keuls test, $\alpha=0.05$)

DISCUSSION

The study revealed that the tested crude plant extracts were effective in inhibiting growth of the tested post-harvest loss causing pathogens although in most cases their efficacy varied with the concentration. The results obtained proofed that garlic, ginger and neem extracts contain anti-fungal and anti-bacterial properties by their ability to inhibit growth of the test fungi and bacteria. The findings show that garlic was the most effective crude plant extract in inhibiting the growth of all the test pathogens at the lowest concentration as compared to ginger and neem. In addition, all evaluated concentrations of garlic had significant reduction on both mycelial growth of fungal pathogens and the colony forming units of *Erwinia* hence could be considered as the best alternative for the management of post-harvest rot causing pathogens in tomato. The findings are in agreement with those of other scientists such as Dutta *et al*., (2004), who reported that 10% concentration of crude garlic showed total inhibition of sclerotial production and 20% concentration showed excellent mycelial inhibition of *R.solani* causing sheath blight of rice. Reports of Anjorin *et al*., (2008) showed that garlic effectively inhibited *Fusarium* spp. Bhuiyan *et al*., (2008), found garlic extracts to be effective in controlling growth of *Colletotrichum dematium* at 20 % concentration. Sowjanya and Manohara (2000) also reported that amongst five plant extracts tested, garlic was the most effective completely checking the mycelial growth at 10% concentration. Furthermore, reports by Paradza *et al.* (2011) showed that when garlic and neem extracts were used to control bacterial soft rot, garlic was the most effective in reducing bacterial maceration of the potato tissue.

The study further established that the tested crude plant extracts demonstrated different inhibition ability against the tested pathogens which could be attributed to differences in degree of sensitivity of each of the test pathogen to the different doses of the extracts. *Fusarium* spp. proofed to be the most sensitive pathogen in all the plant extracts tested with Neem leaf extract showing to be the most effective extract on the *Fusarium* spp. These results agree with the report of Hassanein *et al*. (2008), where four concentrations of neem extracts were evaluated and the lowest concentration (20 %) effectively suppressed mycelial growth of *F. oxysporum* (100 %).According to Amadi and Olusanmi (2009), extracts from garlic and neem have anti-microbial properties against a wide range of pathogens but garlic was the most effective. Garlic contains a compound known as allicin which is readily membrane-permeable and undergoes thiol-disulphide exchange reactions with free thiol groups in proteins and the compound is anti-bacterial, anti-fungal and anti-viral (Miron *et al*., 2000 and Daniela *et al*., 2008). When garlic bulbs are damaged a substrate alliin mixes with the enzyme alliin-lyase and forms a volatile compound which is fungicidal and disrupts fungal cell metabolism due to oxidation of proteins (Slusarenko *et al.,* 2008). Such properties may be the basis for anti-microbial action. According to Alan *et al*. (2008) reduction in disease was due to direct action against the pathogen since no accumulation of salicylic acid was observed after treatment with garlic crude extract to control downy mildew of

Arabidopsis. Reports by Udo *et al*. (2001) showed inhibition of growth and sporulation of fungal pathogens in *Ipomea batatas* by garlic extracts.

Stangarlin *et al*. (2011) revealed that aqueous extract of ginger at different concentrations had effect on the mycelial growth and sclerotial production of *Sclerotina sclerotiumin vitro*. The anti-microbial property of ginger in reducing the mycelial growth of fungal pathogens are in agreement with the results of this study. The inhibitive effect was proportional to the concentration of the crude extract: the higher the concentration the higher the inhibitory effect. According to Ijato (2011), extracts of *Z. officinale* and *Ocimum gratissimum* were mycotoxic to *F. oxysporum*, *A. flavus* and *A. niger* that causes post-harvest rot of yam tubers and that the effectiveness of the extracts increased with increase in concentration as was observed in this study. Chiejina and Ukeh (2012) reported that the efficiency of ginger extracts may be due to high contents of alkaloids contained in it. Reports of Okwu (2004) ranked alkaloids as the most significant, efficient and therapeutic plant substances. Results of Chuku *etal*. (2010) showed that ginger extract at a concentration of 3 gm/20ml of extract completely inhibited fungal growth.

Reports from Nahed (2007) showed that cold extracts of *A. indica* inhibited growth of *F. oxysporum*, which causes rot of cucumber. Cassava anthracnose caused by *C. gloesporides* was controlled using neem extracts (Fokunang *etal*., 2000). Hoque *et al*. (2007) reported that neem contains a compound known as mahmoodin which is active against gram-positive and gram-negative bacteria. This supports the finding of this study which showed a significant slowed growth of *Erwinia* spp. in petri dishes treated with neem extracts. However the results from this study did not agree with those of Chuku *et al*. (2010) who reported that garlic was not effective in controlling fruit rot causing pathogens.

CONCLUSION

Ginger, garlic and neem crude plant extracts were shown to be potential inhibitors to tomato fruit rot causing pathogens at different concentrations. They were found to have anti-microbial compounds that act against the pathogens. Each extract was found effective against the test pathogens but efficacy varied with different extract concentrations. The findings of this study are in line with others that have shown that crude plant extracts could provide an alternative means for the management of post-harvest rot causing pathogens in tomato fruits. Results of this study thus provide an important step in developing plant based bio-pesticides for the management of fruit rots because the tested plants extracts are readily available and cheap. Adoption of the plant extracts could offer a viable solution to the management of post-harvest pathogens in tomato hence safeguarding plant, human and animal health as well as the environment.

RECOMMENDATIONS

There is need for further research to determine residual levels of the plant extracts on fruits and their implication on the health of the consumers.

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6.3 Evaluation of Belt 480 SC (*Flubendiamide 480 g/L)* against tomato leaf miner, *Tuta absoluta* at Mwea in Kirinyaga County

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ABSTRACT

Tomato, *Lycopersicon esculentum* Mill is one of the major vegetable crops grown in Kenya, mainly for domestic consumption. The vegetable has many health benefits including excellent source of vitamin A, B6, C, E and K. The main tomato growing areas include, Kirinyaga, Kajiado and Taita Taveta counties. However, tomato production is faced with many production challenges, including, soil types, water requirements, weeds, disease and arthropod pests. The tomato leaf miner, *Tuta absoluta*, a major invasive pest of tomato was reported for the first time in Kenya in April, 2014. The pest was reported as attacking tomato in both green house and field leading to great losses in both yields and quality. Following the outcry by farmers, Bayer EA Ltd in collaboration with KALRO conducted field experiments to evaluate the efficacy of Belt 480 SC *(Flubendiamide 480 g/L)* against the leaf miner. The evaluation was carried out in two sites, namely Redsoil and Kiorugari in Mwea, Kirinyaga County between July and December 2014. Four treatments consisting of Belt 480 SC at (2, 4 and 8 ml per 20 Litres of water) and untreated control were applied on tomato, variety Kilele F1. The experiment was set up in a randomized complete block design with 4 replicates. Data on *Tuta* larvae, mines per leaf, total fruit yield and percentage marketable yield were processed by use of SAS statistical package. In conclusion, Belt 480 SC at 2 ml in 20 litres of water which recorded 96-100% as compared to the untreated control with 62-73% as

marketable yield was recommended for the management of tomato leaf miner, *Tuta absoluta*.
Key words: **Tomato, Belt SC 480, tomato leaf miner, *Tuta absoluta***

INTRODUCTION

Vegetable sub-sector is an important and integral part of the Kenya's agricultural development. It is important in attaining food security and improving livelihood for smallholder farmers. The major vegetables produced in the country include cabbages, tomatoes and kales. Tomato is the third most important vegetable in the country in terms of tonnage produced. In 2013, the area under tomatoes was 22,865 hectares planted mainly under irrigation. The total production was 494,036.5 tons with a value of KES 14.1 Billion HCDA (2013). Tomato growing is a countrywide activity and is done mainly by small scale farmers including the youth. Pests and diseases are a major challenge in production of tomatoes. Diseases of economic importance include bacterial wilt and late blight. The common pests are African bollworm, red spider mites and whiteflies. In 2014, the Ministry of Agriculture, Livestock and Fisheries reported that a new invasive pest, identified as tomato leaf miner, *Tuta absoluta* was present in most of tomato growing areas of the country (Karanja T. (2014), Koskei F. (2014). The pest was found to attack tomatoes both in the field and also in screen-houses specifically in Isiolo, Meru, Kirinyaga, Nyeri, Kajiado and many other counties in the country, (Kambo *et. al.,* (2014), IPPC, (2014), Kasina and Lusike (2014).

The pest is a native of South America, particularly Peru, Bolivia and Chile where it was described in 1917. The pest has been reported in Europe particularly, Spain in the year 2006. It was later reported in North America and other European Countries including Germany, Netherlands, U.K., Italy and Turkey in 2010 (Nicholas *et. al.* (2010). The pest established in Africa as follows:-

Morocco 2007, Tunisia 2008, Canary Islands 2008, Algeria 2008, Senegal 2012, Niger 2012 Sudan 2012 and Ethiopia 2012 (Muniappan R (2013). The spread of the insect over long distances is as a result of trade in infested tomato fruits and ability of the adult insects to move several kilometers by flying or drifting with the wind. Other factors that have led to the global rapid distribution of this pest include: Wide spread tomato cultivation, high number of insect pest generations (up-to 10) per year, Lack of specific natural enemies and fast development of resistance to insecticides.

In view of this, Bayer EA Ltd and Kenya Agricultural and Livestock Organization partnered together with the aim evaluating Belt 480 SC (*Flubendiamide 480 g/L)* insecticide against this invasive tomato for registration as a pest control product (PCPB, 2012). No standard local check was used in the trial since there is no currently registered Soluble Concentrate (SC) product in the control of the tomato leaf miner in Kenya.

OBJECTIVES:

i. To determine the efficacy of Belt 480 SC (*Flubendiamide 480 g/L)* against *Tuta absoluta* on tomatoes.
ii. To assess the effect of *Tuta absoluta* on tomato yield and quality

MATERIALS AND METHODS

Trial site and study design

The study was carried out at Mwea, Kirinyaga County, in two different locations - Redsoil and Kiorugari - between July 2014 and December 2014. Tomato variety Kilele was transplanted from a nursery and planted at a spacing of 90 x 45 cm in 4 x 4 metre plots (AEI (2011). The plots were separated with 2-metre paths between the plots and blocks. Agronomic practices including weeding and fertilizer application were applied as required.

The treatments used were 3 rates of Belt 480 SC *(Flubendiamide 480 g/L)* and an untreated control as shown below (Table 1). The treatments were arranged in a randomized complete block design (RCBD) with 3 replications. All Belt 480 SC treatments were applied at a weekly interval using a lever-operated knapsack sprayer. Control plots were not treated with any product (Ciba Geigy, 1981).

Table 7: Treatments used in evaluation of Belt 480 SC

Product	Active Ingredient	Rate per 20 litre of water	Rate/ha
Belt 480 SC	*Flubendiamide 480 g/L*	2.0 ml	0.05 L
Belt 480 SC	*Flubendiamide 480 g/L*	4.0 ml	0.10 L
Belt 480 SC	*Flubendiamide 480 g/L*	8.0 ml	0.20 L
Control	Nil	0.0 ml	0.00 L

Sampling

Data on tomato leaf miner was collected on weekly basis, starting from the 2nd week after transplanting. Five plants per plot were tagged and leaf damage (mined) as a result of *Tuta absoluta* infestation was thoroughly scrutinized and counts of mines were recorded. Live *Tuta* larvae on the treatment plots were recorded in well-structured data sheets. Yield data was collected through harvesting of fruits, which were then graded into marketable and unmarketable fruits i.e. undamaged and damaged fruits, respectively.

DATA ANALYSIS

Data on mines per leaf, total fruit yield and percentage marketable yield were processed by use of two-way Analysis of Variance (ANOVA) and Least Significant Difference was used for the separation of treatment means (Montogomery, 1976). SAS statistical package was used for the analysis (SAS, 2014). Data was transformed using square root formula to normalize it where it was found to be skewed, before carrying out the ANOVA.

RESULTS AND DISCUSSION

Effect of Belt 480 SC against tomato leaf miner at Kiorugari

There was a significant difference between treated and untreated plots with regard to the number of leaves showing *Tuta* damage from 2 weeks after the first insecticide application and this trend continued throughout the experimental period as recorded at 4, 6, 8 and 10 weeks after the first insecticide application **(Table 1).** Plots under all the 3 rates of Belt 480 SC (2.0, 4.0 and 8.0 ml/20 L of water) showed significantly few damaged (mined) leaves compared with the untreated control plots. The numbers of mined leaves in plots treated at the three rates of Belt 480 SC were not significantly different from each other at the various sampling times.

Table 8: Larvae populations at various sampling times at Kiorugari

		No. of mined tomato leaves per plant (*x*), at various periods (Weeks after 1st insecticide application)						
Treatment	**Rate/20 L water**	**0**	**2**	**4**	**6**	**8**	**10**	**Pooled means**
Control	0.0 ml	2.82b	4.72a	5.87a	5.40a	5.15a	5.32a	**5.04a**
Belt 480 SC	2.0 ml	3.79a	2.49b	1.09b	0.94b	0.88b	0.88b	**1.55b**
Belt 480 SC	4.0 ml	3.31b	2.20b	1.16b	0.97b	1.13b	0.88b	**1.51b**
Belt 480 SC	8.0 ml	2.88b	1.99b	1.13b	0.97b	0.88b	0.88b	**1.37b**
LSD (p=0.05)	-	**0.83**	**1.21**	**0.58**	**0.48**	0.66	**1.04**	**0.54**
P-value	-	**0.09**	**‹0.001**	**‹0.001**	**‹0.001**	**‹0.001**	**‹0.001**	**‹0.001**
CV (%)	-	**13.01**	**34.90**	**20.58**	**19.18**	**26.94**	**26.14**	**44.80**

Means in the same column followed by the same letter are not significantly different at p= 0.05 level.
The figures presented in Table 2 are (√ *x*+0.5) **= Square root transformation,** (√ *x*+0.5), **where *x* = No. of mined leaves/plant**

The number of live *Tuta absoluta* larvae on tomato leaves was significantly reduced 2 weeks after the first insecticide application. This trend was similar throughout the season as recorded in 4, 6, 8 and 10 weeks after the first insecticide application **(Table 2).** All the 3 rates of Belt 480 SC (2.0, 4.0 and 8.0 ml/20 L of water) showed significantly lower Tuta larvae population densities than the untreated control plots. The pooled (overall) means revealed that Belt 480 SC was effective against the tomato leaf miner at all the three rates of application (2.0, 4.0 and 8.0 ml/20 L of water) as evidenced by low larvae infestation levels compared with the control. The Tuta population densities at the three application rates were not significantly different from each other.

Table 9: Larvae populations under various treatments at Kiorugari, Mwea

		No. of live *Tuta absoluta* larvae per leaf *(x)*, (Weeks after 1st insecticide application)						
Treatment	**Rate/20 L water**	**0**	**2**	**4**	**6**	**8**	**10**	**Pooled means**
Control	0.0 ml	1.88a	3.27a	3.80a	2.79a	2.58a	2.67a	2.94a
Belt 480 SC	2.0 ml	1.95a	1.09b	0.71b	0.71b	0.71b	0.71b	0.93b
Belt 480 SC	4.0 ml	1.61a	1.03b	0.71b	0.71b	0.71b	0.71b	0.86b
Belt 480 SC	8.0 ml	1.27a	0.95b	0.71b	0.71b	0.71b	0.71b	0.81b
LSD (p=0.05)	**-**	**1.21**	**0.75**	**0.18**	**0.44**	**0.13**	**0.29**	**0.26**
P-Value	**-**	**0.544**	**‹0.001**	**‹0.001**	**‹0.001**	**‹0.001**	**‹0.001**	**‹0.001**
CV (%)	**-**	**36.20**	**38.80**	**9.92**	**20.08**	**9.14**	**12.14**	**37.07**

Means in the same column followed by the same letter are not significantly different at by LSD at p= 0.05 level.
The figures presented in Table 3 are (√ x+0.5) **= Square root transformation,** (√ x+0.5), **where x = *Tuta absoluta* larvae /leaf**

There was no significant difference in the total yield for tomatoes where Belt 480 SC was applied or not (Table 3). However, there were highly significant differences between plots with pesticide application and untreated controls with regard to the quantities of unmarketable and marketable yields. Untreated control plots had a significantly lower proportion of marketable yield, which was about 62% of the total yield, than the Belt-treated plots, which had high proportions of marketable yields, ranging from 92-96% **(Table 3).** The three different Belt 480 SC concentrations did not give statistically different yields.

Table 10: Tomato yields and marketability under Belt 480 SC treatments

Treatment	Rate/20 L water)	Total yield/plot (g)	Unmarketable yield (g)	Proportion of marketable yield (%)
Control	0.0 ml	3,440a	1,319.0a	61.6b
Belt 480 SC	2.0 ml	2,673a	104.0b	96.1a
Belt 480 SC	4.0 ml	2,849a	233.3b	91.8a
Belt 480 SC	8.0 ml	3,103a	177.3b	94.3a
LSD (p=0.05)	**-**	843.6	332	10.1
P-Value	**-**	**0.305**	**‹0.001**	**‹0.001**
CV (%)	**-**	**54.60**	**141.51**	**23.13**

Means in the same column followed by the same letter are not significantly different at by LSD at p= 0.05 level

Effects of Belt 480 SC against tomato leaf miner at Redsoil, Mwea

There was significant difference in the number of leaves showing *Tuta* damage across the various treatments at Redsoil **(Table 4).** Plots treated with various concentrations of Belt 480 SC showed significantly lower number of infested leaves compared with control plots throughout the season. However, there was no statistical difference amongst the numbers of leaves exhibiting *Tuta* damage under the three Belt 480 SC concentrations.

Table 11: Number of tomato leaves with *Tuta* mines under various dosages of Belt 480 SC at Redsoil, Mwea

		No. of mined tomato leaves per plant (*x*), at various periods (Weeks after 1st insecticide application)						
Treatment	**Rate/20 L water**	**0**	**2**	**4**	**6**	**8**	**10**	**Pooled means**
Control	0.0 ml	2.68a	2.41a	3.87a	5.36a	5.17a	5.78a	4.52a
Belt 480 SC	2.0 ml	2.06ab	1.22b	0.97b	1.30b	1.26b	1.05b	1.16b
Belt 480 SC	4.0 ml	1.84b	1.22b	0.86b	0.88b	0.97b	0.88b	0.96b
Belt 480 SC	8.0 ml	2.27ab	1.16b	0.97b	0.88b	0.80b	1.05b	0.97b
LSD (p=0.05)	**-**	**0.69**	**1.03**	**0.71**	**0.70**	**0.58**	**0.61**	**0.45**
P-Value	**-**	**0.104**	**0.054**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
CV (%)	**-**	**15.61**	**56.31**	**35.42**	**27.32**	**23.19**	**23.00**	**45.81**

Means in the same column followed by the same letter are not significantly different at by LSD at p= 0.05 level

The figures presented in Table 5 are ($\sqrt{x}$+0.5) **= Square root transformation,** ($\sqrt{x}$+0.5), **where x = No. of mined leaves/plant**

The number of live caterpillars recorded on tomato leaves was statistically different across the various treatments **(Table 5).** The three Belt 480 SC concentrations were not significantly different from each other but they were significantly different from the untreated control, which had the highest infestation levels.

Table 12: Mean number of live larvae per leaf on tomato plots grown under various treatments at Redsoil, Mwea

Treatment	Rate/20 L water	0	No. of live *Tuta absoluta* larvae per leaf (x), (Weeks after 1st insecticide application) 2	4	6	8	10	Pooled means
Control	0.0 ml	2.17a	1.37a	2.36a	2.78a	2.76a	2.89a	2.43a
Belt 480 SC	2.0 ml	1.62a	0.71b	0.71b	0.71b	0.88b	0.71b	0.74b
Belt 480 SC	4.0 ml	2.52a	0.71b	0.71b	0.71b	0.71b	0.80b	0.73b
Belt 480 SC	8.0 ml	1.79a	0.80b	0.71b	0.71b	0.71b	0.71b	0.73b
LSD (p=0.05)	**-**	**1.14**	**0.35**	**0.22**	**0.24**	**0.38**	**0.39**	**0.20**
P-Value	**-**	**0.305**	**0.002**	**‹0.001**	**‹0.001**	**‹0.001**	**‹0.001**	**‹0.001**
CV (%)	**-**	**28.10**	**32.04**	**16.33**	**15.85**	**24.82**	**24.94**	**33.20**

Means in the same column followed by the same letter are not significantly different at by LSD at p= 0.05 level.
The figures presented in Table 6 are ($\sqrt{x}+0.5$) = **Square root transformation,** ($\sqrt{x}+0.5$), **where x = *Tuta absoluta* larvae /leaf**

At Redsoil site, all the 3 Belt 480 SC applications resulted to production of 100% marketable yield compared with control, which recorded 76% marketable yield (Table 6). These results show that the pesticide application had significantly higher marketable yields compared with control.

Table 13: Mean yield of tomatoes grown under various treatments at Redsoil, Mwea

Treatment	Rate/20 L water	Yield/plot (g)	Marketable yield (g)	Percentage marketable yield
Control	0.0 ml	9408a	6855b	72.86b
Belt 480 SC	2.0 ml	9371a	9371ab	100.00a
Belt 480 SC	4.0 ml	11517a	11514a	99.97a
Belt 480 SC	8.0 ml	11429a	11429a	100.00a
LSD (p=0.05)	**-**	3915.6	3809.8	6.04
P-Value	**-**	**0.528**	**0.056**	**‹0.001**
CV (%)	**-**	**65.45**	**67.84**	**11.20**

Means in the same column followed by the same letter are not significantly different at by LSD at p= 0.05 level

CONCLUSION

The results obtained from the two trial sites, namely Redsoil and Kiorugari at Mwea, Kirinyaga County revealed that Belt 480 SC at the three tested rates (2.0, 4.0 and 8.0 ml/20 L of water) is effective against the tomato leaf miner, *Tuta absoluta.* The three different concentrations produced statistically similar results and led to significantly lower *T. absoluta* infestation levels than the untreated controls. Application of Belt 480 SC also led to significantly high proportions of marketable tomato fruit yields in comparison to untreated controls which registered large quantities of unmarketable fruits.

The Kiorugari site had a relatively higher *Tuta absoluta* infestation than the Redsoil site. This translated to higher numbers of damaged tomato leaves, higher number of larvae and higher proportions of unmarketable fruits yields at Kiorugari than at Redsoil at comparable treatments. This shows that a high rate of application of Belt 480 SC would be appropriate under conditions of high infestation by this pest. Therefore, it is recommended that Belt 480 SC be applied at the rate of 2.0 to 4.0 ml in 20 litres of water for management of *T. absoluta* on tomatoes.

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6.4 Developing an effective pest management strategy for French beans in Kenya to protect export market

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ABSTRACT
In Kenya, French bean (*Phaseolus vulgaris* L.) production is majorly hampered by diseases and pests, which most farmers manage using synthetic pesticides, usually in a manner that results to exceeding maximum residue limits (MRLs) set by the import markets. Kenya has had challenges in managing these MRLs and thus this study was

carried out to provide best approach to the management of the pests that may result to meeting MRLs requirements and ensuring the product is of high quality. Treatments entailed planned use of synthetic pesticides, biological control (biocontrol) products and Integrated Pest Management (IPM) system. Trial was arranged in randomized complete block design with plots measuring 3m by 4m replicated four times. Data collected included recording number of pests and feeding marks on randomly selected plants per plot, every fortnight from germination till end of season. Yield data was collected twice weekly from 42 days after germination. Data was analysed using Genstat Discovery edition. Analysis of variance was performed at 95% confidence limit to significant effects across the treatments. The results show no significant difference in the number of thrips across various management practices in season 1 ($P=0.286$) and season 2 ($P=0.503$). Pesticide-applied plots had however higher infestation levels compared to the rest in both seasons. Aphids were significantly different across various management practices in season 1($P=0.000$) and 2 ($P=0.002$). They were significantly lower in IPM applied plots and those under biocontrol compared with the pesticide-treated plots in both seasons. A highly significant ($P<0.001$) difference in the number of whiteflies was recorded in both seasons. Whiteflies were significantly lower in IPM plots compared with pesticide-controlled plots. Considering that IPM provided effective management of the various pests it is recommended that the system be optimized to ensure reliability and farmer adoption for French bean production.
Key words: maximum residue limits, French beans, Agronets, biocontrol, pesticides

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is the second most important horticultural export crop after cut flowers in Kenya (Stetter and Folker, 2000). The beans though grown mainly for export (Nderitu *et al.,* 2007) are also gaining popularity in domestic urban centers. Arthropod pests affecting French beans include thrips, aphids, red spider mites, white flies among others (Nderitu *et al.,* 2007). Diseases include rust, fusarium wilt and blights (Monda *et al,* 2003). The abuse of pesticides has resulted in many negative externalities. Pesticides should be toxic to target organisms only, degrade naturally and within a short time (Rosell *et al*., 2008) but most pesticides kill non-targeted organisms and persist for long in the environment resulting in pollution and more stringent measures on allowed pesticide maximum residue levels. Pest management strategies tested in the past have mostly involved independent use of a strategy without considering a more integrated approach. This study seeks to provide a strategy that is environmentally safe with a guarantee of increased quality yield.

MATERIALS AND METHODS

Experiments were carried out at the Kenya Agricultural and Livestock Research Organisation research centres in Mwea, Kabete and National Sericulture Centre, Kenya, in two planting seasons. KALRO Mwea is found in Kirinyaga County lying between latitudes 37^{o}13′E and 37^{o}56′E and longitudes 0^{o}10′S and 0^{o}54′E. Its temperatures range from 16.5^{0}C to 29^{o}C with an annual rainfall of 950mm (Kamanu *et al.,* 2012). KALRO Kabete is located about 15 km to the West of Nairobi city and lies at Latitude 1^{o} 15′S and

Longitude 36° 44′E (Sombroek et al., 1982). It has a bimodal distribution of rainfall, with mean annual temperature of 18^0 C (Mburu, 1996). The NSRC is located in Murang'a County and has an average temperature of 19.8^0 C. It receives an annual rainfall of 840 mm and is located at an altitude of 1499m ASL. (MOA Kandara, 2012). the study entailed a complete randomized block design layout with four replications. Pest data was collected every fortnight from germination date till the end of harvesting period. The plots measured 3m by 4m in all sites. The Serengeti French bean variety seeds supplied by Syngenta Company were treated as shown in Table 1. Data analysis were done using Genstat Discovery edition (Anonymous, 2015). Thrips data was square root transformed to fit assumption of analysis of variance (ANOVA). Where there was no significant difference, pooled analysis was carried out.

TABLE 1: Treatment regimes

Treatment Regime	Description
Control	Control (no seed dressing except with the standard Thiram)
Pesticide use	Synthetic Pesticide use only
Integrated Pest Management	Integration of Pesticides, Bio-control and Agro-net technology
Bio-control only	Biological control use only

RESULTS

General outlook

Results show no significant difference in the number of thrips across various management practices in both season 1 (P=0.286) and season 2 (P=0.503). This may have been due to the effectiveness of the various treatments in combating thrips. Aphids were significantly (P=0.000; P=0.002) different across various management practices in season 1 and 2, respectively. They were significantly lower in IPM plots and those under biocontrol compared with the pesticide-controlled plots in both seasons. A highly significant ($P<0.001$) difference in the number of whiteflies was recorded in both seasons. Whiteflies were significantly lower in plots under IPM compared with pesticide-controlled plots.

Effects across the sites

In both seasons whiteflies were significantly lower in plots under IPM and biocontrol compared with pesticide treated plots at Kabete but these were not significantly different at Mwea. Red spider mites were significantly lower in plots under biocontrol compared with IPM and pesticide treated plots in the first and second season, however in the second season they were quite high in IPM plots in Thika as compared to Mwea.

Table 2a: Mean number of pests infesting French beans at Mwea and Kabete

Treatment	**Thrips**		**Aphid colonies**		**Whiteflies**	
	Kabete	**Mwea**	**Kabete**	**Mwea**	**Kabete**	**Mwea**
Control	8.08a	25.12	4.92b	1.46a	1.38a	15.17b
Biocontrol only	18.12ab	22.00	2.38ab	.42b	3.25b	12.46ab
IPM	20.42b	16.04	0.88a	.08b	4.92b	8.88a
Pesticides only	26.62b	23.88	4.25b	.38b	11.42c	14.96b
P value	.026	.422	.002	.000	.000	.004
N	24	24	24	24	24	24

Table 2 b Mean number of pests infesting French beans at Mwea and Thika

Plots treated with	**Thrips**		**Aphid colonies**		**Whiteflies**	
	Thika	**Mwea**	**Thika**	**Mwea**	**Thika**	**Mwea**
Control	1.85	4.45	10.083a	2.746ab	19.79b	36c
Biocontrol	1.82	4.05	5.250a	2.056a	15.54b	21.7b
IPM	1.45	4.05	3.000a 00 a	1.686a	2.62a	4.25a
Pesticides	1.96	0.9	5.958a	2.141a	15.62b	21.85b
P value	0.4	0.587	0.002		<.001	<.001
N	20	20	20		20	20

Diseases

During season one Root rot, Rust, Halo blight and viral diseases were present in low levels in both sites but Anthracnose and Pythium appeared only in Kabete. The diseases were not severe during the two trials as they were well managed by the different treatment applications. Root rot and rusts were recorded in the second season. Rust appeared at fruiting and harvesting period in both seasons.

French beans yields grown under different treatments.

IPM plots recorded significantly (37,192.411; p=.004) higher French bean yields in both seasons and in all sites. This was followed by those under pesticide treatment (28,302.96bc) and then biocontrol (13,836.13ab).

CONCLUSIONS AND RECOMMENDATIONS

From the study IPM was a better management strategy for the French bean pests as it entailed use of both pesticides and biocontrol products but with the inclusion of the Agronets. Other than physically barring pests from accessing the crop Agronets also modify the micro-climate conditions exposing plants to factors that stimulate faster growth. Improvement of IPM for example by registering biocontrol products that have not been registered should be considered as seen from the results showing their great efficiency in pest control.

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6.5 Evaluation of Tihan OD 175 *(Flubendiamide 100 g/L + Spirotetramat 75 g/L)* against sucking and chewing arthropod pests of cotton at Mwea in Kirinyaga County

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ABSTRACT
A field experiment to evaluate the of efficacy of Tihan OD 175 *(Flubendiamide 100 g/L + Spirotetramat 75 g/L)* against sucking and chewing arthropod pests of cotton was carried out in the field at conducted at KARI-Mwea between October 2014 and June, 2015. Cotton variety, HART 89M, was grown under rain fed conditions using the currently recommended agronomic practices. Cotton variety, HART 89M was planted in a

randomized complete block design with 4 replicates. The crop was grown using recommended agronomic practices. The treatments used were 3 rates of Tihan OD 175, local check, Thunder 145 OD and untreated control. Tihan OD 175 at 0.20 and 0.25 L ha^{-1} significantly reduced cotton aphids, African bollworms and mealybug populations as compared to the untreated control plots. The results obtained in this trial show that Tihan OD 175 at the rate of 0.20 - 0.25 litres in 500 litres of water per hectare was found to be effective against cotton aphids, bollworms and cotton mealybugs.
Key words: **Cotton variety, Tihan OD 175, aphids, African bollworm, mealybugs**

INTRODUCTION

Cotton (*Gossypium hirstum* [L]) is one of the most important cash crops in Kenya. The crop was introduced in Kenya in the early 1900's by the British colonial administration. It is grown in several agro ecological zones, mainly in the semi-arid regions of Eastern, Central, Nyanza, Coast, Western and Rift Valley provinces. Since its introduction, the crop has been characterized by fluctuating production trends. Between 1965 and 1984, the annual national lint production grew from 20,000 to 70,000 bales and the textile-apparel industry was the leading manufacturing industry in size and employment. The increase was due to both government and donor support aimed at reducing production constraints and achieving self-sufficiency. During the 1980' peak production period, Bura and Hola Irrigation Schemes produced about 40% of the national cotton production.

However by mid-1990's the lint production declined to an average of 20,000 bales due to liberalization of the cotton industry. In 2005, the government invested a lot of funds for the revival of the cotton industry. From that time todate, there has been a gradual increase in cotton production and the current national production is on the range of 50,000 bales per year. Cotton is the most important fibre crops that provide fibre for the textile industries and is a source of income to resource-poor farmers. The seeds are also used as feed for livestock and as food to human beings (Lutrel, et al., 1994). In Kenya, up to 4000 kg ha^{-1} and 900 kg ha^{-1} of seed cotton have been recorded in research centres and farmers fields respectively (Ikitoo. *et al*,. 1989). This wide yield difference is probably due to poor agronomic practices, low soil fertility, rainfall patterns, disease and arthropod pests (Munro, 1987, Ikitoo *et al*., 1989).

Cotton is attacked by several arthropod pests as early as from germination stage to the end of season. Some of the common early season pests are the cotton aphid (A*phis gossypii*), red spider mite (*Tetranychus telarius*), thrips (*Frankliniella sp*), African bollworm (*Helicoverpa armigera*), tobacco whitefly (*Bemisia tabaci*) and cotton mealybug *(Phenacoccus spp*.). The African bollworm is the most serious pest, appearing at flowering stage from 8-9 weeks after plant emergence. Cotton stainer (*Dysdercus sp*) attack the crop during the opening of bolls, staining the lint which lowers the quality of seed cotton (Munro, 1987).

The main management strategy currently is by application of synthetic pesticides. Many tested synthetic pesticides are effective against cotton pests. However, in order to reduce chances of insect developing resistance to the synthetic pesticides, there is need to continually evaluate new pest control products (Munro, 1987). This would ensure that there are enough pesticides for control of cotton pests including the cotton mealbugs. Tihan OD 175 *(Flubendiamide 100 g/L + Spirotetramat 75 g/L)* is an Oil Dispersion, currently there is no OD that has the same active ingredients as Tihan OD 175. In view of these the author of this report chose Thunder 145 OD *(Imidacloprid 100g/L + Betacyfluthrin 45 g/L)* which is already in the market and controls a wide range of sucking pest as a local check. Thunder is registered (PCPB (CR) 0739) for the control of thrips, aphids and whiteflies in horticultural crops (Tomatoes and French beans (PCPB, 2012).

OBJECTIVES

To determine the effective dosage of Tihan OD 175 *(Flubendiamide 100 g/L + Spirotetramat 75 g/L)* against mealybugs, caterpillars, red spider mites, aphids, white flies, thrips, African bollworm and cotton stainers

To compare the efficacy of Tihan OD 175 *(Flubendiamide 100 g/L + Spirotetramat 75 g/L)* with that of the local check, Thunder OD 145 *(Imidacloprid 30g/L + betacyfluthrin-13.5 g/L*

To determine the effect of the treatments on the natural enemies and other non- target arthropods

MATERIALS AND METHODS

The experiment was conducted in the field at KARI-Mwea during the 2014/15 cotton growing season. Cotton variety, HART 89M was planted in October, 2014. One seed per hill was planted at a spacing of 30 cm within rows and 100 cm between rows, the crop was planted in plots measuring 5 by 5 m and arranged in a randomized complete block design with 4 replicates. All the plots were separated by a 2 m path between blocks and 1 m path between plots. The crop was grown under rain fed conditions using the currently recommended agronomic practices. Cotton arthropod pests were allowed to infest the crop naturally. To avoid bias during data collection all treatments were marked with number codes written on metallic labels and placed in each plot. Foliar treatments were applied on two weekly basis from 5th March, 2015 to 18th April, 2015.

Foliar treatments used in the experiment included:-

Treatments:

Product	**Active Ingredient**	**Product Rate/ha**
Tihan OD 175	*Flubendiamide 100 g/L + Spirotetramat 75g/L*	0.15 L
Tihan OD 175	*Flubendiamide 100 g/L + Spirotetramat 75g/L*	0.20 L
Tihan OD 175	*Flubendiamide 100 g/L + Spirotetramat 75g/L*	0.25 L
Thunder OD 145	*Imidacloprid 100 g/L+ betacyfluthrin 45 g/L*	0.30 L
Untreated Control	Nil	-

The foliar sprays were applied using a 15 L knapsack (solo) sprayer fitted with a hollow conical nozzle. During application, the crop was totally covered with the spray solution. Tihan OD 175 *g/L* was tested against cotton mealybugs, aphids, African bollworm and thrips. The effect of Tihan OD 175 *g/L* against non-target insects (lady bird beetles and attendant ants) was also assessed. Pre-treatment data was taken one day before the first spray and post-treatment data was taken on two weekly interval starting from 13th March, 2015 to 25th April, 2015. During sampling, aphid counts were done on the under side of the leaves taken from each of 10 randomly selected plants in each plot. Foliar pests were counted from the topmost 5 mainstem node leaves. During sampling the numbers of bollworm larvae per plant were recorded. Cotton mealybugs were collected from three randomly selected twigs (10 cm long) from five tagged plants in each plot. The three twigs were cut off the plants and put in a sampling polythene bag and tied properly to prevent the mealybugs and the attendant ants from escaping. The polythene bags containing the mealybugs and ants were taken to the laboratory and the number of mealybugs and attendant ants were recorded in well designed data sheets.
Data on mealybugs, aphids, thrips and African bollworm was transformed using $\sqrt{x}+0.5$ (Montgomery, 1976) and subjected to 2- way analysis of variance (ANOVA). To determine the effect of different rates of Tihan OD 175 *g/L* and Thunder OD 145 *at* 0.30 L ha^{-1} *as* compared with the untreated control, was done by use of, SAS statistical package (SAS, 2015). Mean separation was done by LSD test at p=0.05 level of significance.

RESULTS AND DISCUSSION

Table 1-7 show the efficacy of Tihan OD 175 at 0.15, 0.20 and 0.25 L ha^{-1} and local check Thunder 145 OD at 0.30 L ha^{-1} as compared to the untreated control.

Cotton aphid *(Aphis gossypii)*

Results presented in Table 1 show that there was no significant difference in aphid population among all the treatments prior to insecticide application.
However, cumulative aphid counts through out the experimental period show that there was no significant difference in aphid population recorded in plots treated with Thunder 145 OD at 0.30 L ha^{-1} and those treated with Tihan 175 OD at 0.15, 0.20 and 0.25 L ha^{-1} with each recording 5.75, 11.61, 7.34 and 10.32 aphids per plant respectively. However, the untreated control plots recorded significantly high aphid populations of 19.39 aphids per leaf as compared to Thunder 145 OD at 0.30 L ha^{-1} and Tihan OD 175 at 0.15, 0.20 and 0.25 L ha^{-1} which recorded 5.75, 11.61, 7.34, 10.32 aphids per leaf respectively.

Table 1: Treatment means showing the efficacy of Tihan OD 175 against cotton aphids, *Aphis gossypii*

Treatment	Rate/ha	Pre-treatment	Weeks after 1st Pesticide application						
		0	3	4	5	6	7	Pooled Means ($\sqrt{x+0.5}$)	Aphids/leaf (x)
		Square root (x+0.5)							
Tihan OD 175	0.15 L	4.07a	4.00a	3.75a	2.37bc	5.34a	1.13bc	3.48ab	11.61
Tihan OD 175	0.20 L	2.33a	1.56b	1.91a	2.64bc	5.75a	2.48bc	2.80b	7.34
Tihan OD 175	0.25 L	3.19a	2.20ab	3.17a	3.16ab	6.25a	2.85b	3.29b	10.32
Thunder 145 OD	0.30 L	2.19a	1.34b	2.91a	1.19c	4.15a	0.71c	2.50b	5.75
Untreted control	-	2.19a	4.3a	4.06a	4.61a	5.46a	6.82a	4.46a	19.39
LSD (p=0.05)	-	1.96	2.34	2.56	1.75	2.63	2.1	1	
P-**Value**	-	0.221	0.044	0.454	0.013	0.548	0.0001	0.002	
CV (%)	-	46.45	57.92	53.65	41.6	32.38	49.81	54.46	

Means in the same column followed by the same letter are not significantly different by LSD test at p=0.05 level

Note: x=Number of aphids/leaf

African bollworms *(Helicoverpa armigera)*

Results in Table 2 show that there was no significant difference in African bollworm population density before the application of Tihan OD 175 (0.15, 0.20L, 0.25 L ha^{-1}) and Thunder 145 OD at 0.30 L ha^{-1}. The pooled means show that Tihan OD 175 (0.15L, 0.20L, 0.25 L ha^{-1}) and Thunder 145 OD at 0.30 L ha^{-1} recorded significantly low bollworm populations as compared to the untreated control plots with each recording 0.00, 0.06, 0.00, 0.006 and 0.21 bollworms per plant respectively. However, there was no significant difference in bollworm populations in plots treated with the 3 rates of Tihan OD 175 (0.15L, 0.20L, and 0.25 L ha^{-1}) and Thunder 145 OD at 0.30 L ha^{-1}.

Table 2: Treatment means showing the efficacy of Tihan OD 175 against African bollworm, *Helicoverpa armigera*

Treatment	Rate/ha	Pre-treatment 0	Weeks after 1st Pesticide application 3	4	5	6	7	Pooled Means ($\sqrt{x+0.5}$)	bollworms /plant (x)
		Square root (x+0.5)							
Tihan OD 175	0.15 L	0.71a	0.71a	0.71a	0.71a	0.71a	0.71a	0.71b	**0.00**
Tihan OD 175	0.20 L	0.71a	0.71a	0.71a	0.71a	0.71a	0.71a	0.75ab	**0.06**
Tihan OD 175	0.25 L	0.71a	0.71a	0.71a	0.71a	0.71a	0.71a	0.71b	**0.00**
Thunder 145 OD	0.30 L	0.71a	0.71a	0.71a	0.71a	0.71a	0.71a	0.75ab	**0.06**
Untreted control	-	0.71a	0.84a	0.71a	0.71a	0.71a	0.84a	0.84a	**0.21**
LSD (p=0.05)	**-**	0	0.17	0	0	0	0.17	0.1	
P-Value	**-**	0	0.736	0	0	0	0.43	0.068	
CV (%)	**-**	0	15.15	0	0	0	15.51	24.32	

Means in the same column followed by the same letter are not significantly different by LSD test at p=0.05 level; Note*: x=Number of bollworms/plant*

4.3 Thrips

Results presented in Table 3 show that no significant difference in thrips population density was noted before and after the application of the test pesticide. However, pooled means of thrips population density for the whole experimental period indicate all the 3 rates of Tihan 175 OD and also the local check, Thunder 145 OD at 0.30 L ha^{-1} had no significant effect in the management of thrips on cotton.

Table 3: Treatment means showing the efficacy of Tihan OD 175 against thrips

Treatment	Rate/ha	Pre-treatment	Weeks after 1st Pesticide application						
		0	3	4	5	6	7	Pooled Means (√x+0.5)	thrips /leaf (x)
		Square root (x+0.5)							
Tihan OD 175	0.15 L	1.64a	1.39a	1.43a	1.80ab	2.69ab	2.04a	1.88a	3.03
Tihan OD 175	0.20 L	1.00a	1.06a	0.93a	1.92ab	1.71b	1.85a	1.81a	**2.78**
Tihan OD 175	0.25 L	0.84a	1.00a	1.06a	1.13b	1.90b	1.76	1.66a	**2.26**
Thunder 145 OD	0.30 L	1.00a	0.84a	0.93a	2.39a	3.38a	2.03a	1.97a	**3.38**
Untreted control	-	1.39a	1.06a	0.84a	1.38ab	2.41ab	1.22	1.70a	**2.39**
LSD (p=0.05)	**-**	1.22	0.99	0.84	1.15	1.4	1.36	0.58	
P-Value	**-**	0.631	0.826	0.611	0.214	0.139	0.699	0.836	
CV (%)	**-**	69.19	61.73	53.93	44.4	38.52	50.64	61.09	

Means in the same column followed by the same letter are not significantly different by LSD test at p=0.05 level

Note: x=Number of thrips /leaf

Mealybugs

Results presented in Table 4 show that no significant difference in mealybug population density was recorded in all the treatment plots including the untreated controls before the application of test products. However, cumulative pooled means indicate that a significantly low population of 2.16 mealybugs per leaf was recorded in plots treated with Tihan at 0.25 L ha^{-1} as compared to the untreated control plots which recorded a significantly high population of 3.34 mealy bugs per leaf. On the other hand, unusually high mealybug population of 5.07 mealybugs/leaf was recorded in plots treated with Thunder 145 OD at 0.30 L ha^{-1}. The possible explanation for this is that Thunder 145 OD at 0.30 L ha^{-1} may have killed all the natural enemies resulting in tremendous increase of mealybug populations.

Table 4: Treatment means showing the efficacy of Tihan OD 175 against mealybugs

Treatment	Rate/ha	Pre-treatment	Weeks after 1st Pesticide application						
		0	3	4	5	6	7	Pooled Means (√x+0.5)	mealybugs /leaf (x)
		Square root (x+0.5)							
Tihan OD 175	0.15 L	2.10a	2.11a	2.06a	1.71ab	2.21ab	1.61b	2.03b	3.62
Tihan OD 175	0.20 L	1.79a	1.88a	1.65a	1.35b	1.67abc	1.42b	1.76bc	2.60
Tihan OD 175	0.25 L	2.20a	1.88a	1.42a	1.42b	1.47bc	1.06b	1.63c	2.16
Thunder 145 OD	0.30 L	2.11a	2.42a	2.12a	2.31a	2.32a	2.69a	2.36a	5.07
Untreted control	-	2.20a	2.06a	1.85a	2.04ab	1.45c	1.54b	1.96b	3.34
LSD (p=0.05)	-	0.69	0.69	0.73	0.79	0.75	0.76	0.25	
P-Value	-	0.699	0.464	0.271	0.095	0.069	0.005	<0.0001	
CV (%)	-	21.87	22.15	26.58	29.86	27.44	30.36	25.95	

Means in the same column followed by the same letter are not significantly different by LSD test at p=0.05 level

Note: x=Number of mealybugs /leaf

Attendant ants

Table 5 show the effect of Tihan 175 OD attendant ants. Results obtained show that a significantly high population density of attendant ants were recorded in plots treated with Tihan 175 OD at 0.15 L, 0.20 L and 0.25 L ha^{-1} and also in the untreated control plots with each recording 31.76, 19.66, 15.58 and 10.39 ants/leaf respectively. The results indicate that all the 3 rates of Tihan 175 OD used (0.15 L, 0.20 L and 0.25 L ha^{-1}) had no detrimental effect on attendant ants. On the other hand, Thunder 145 OD at 0.30 L ha^{-1} found to reduce the population of attendant ants to very low levels which is an indication that, it is harmful to the attendant ants which are beneficial insects in a cotton ecosystem.

Table 5: Treatment means showing the effect of Tihan OD 175 attendant ant populations

Treatment	Rate/ha	Pre-treatment	Weeks after 1st Pesticide application						ants/leaf (x)
		0	3	4	5	6	7	Pooled Means ($\sqrt{x+0.5}$)	
		Square root (x+0.5)							
Tihan OD 175	0.15 L	3.34a	4.08a	5.06a	5.47a	4.68a	3.79a	5.68a	**31.76**
Tihan OD 175	0.20 L	4.05a	3.92a	4.41ab	4.37ab	5.42a	4.21a	4.49ab	**19.66**
Tihan OD 175	0.25 L	2.57a	3.03a	3.84ab	3.15ab	5.25a	5.36a	4.01b	**15.58**
Thunder 145 OD	0.30 L	2.82a	3.37a	2.00b	2.54b	2.83a	1.94b	2.65c	**6.52**
Untreted control	-	4.71a	3.46a	3.63ab	3.65ab	3.60a	1.49b	3.30bc	**10.39**
LSD (p=0.05)	**-**	4.74	3.68	2.82	2.65	2.65	1.82	1.25	
P-Value	**-**	0.078	0.973	0.253	0.211	0.228	0.002	**<0.0001**	
CV (%)	**-**	73.21	68.32	49.37	45.88	40.33	36.04	58.7	

Means in the same column followed by the same letter are not significantly different by LSD test at p=0.05 level

Note: x=Number of ants/leaf

Ladybird beetles

Table **6** show that prior to pesticide treatment there was no significant difference between the ladybird beetle populations in all the treatment plots including the untreated control. However, cumulative pooled means show that there was no significant difference in the number of ladybird beetles recorded in plots treated with Tihan at 0.25 L ha^{-1} and the untreated control plots with each recording 0.67 and 1.24 ladybird beetles per plant respectively. This is an indication that Tihan at the rate of 0.25 L ha^{-1} is not harmful to the ladybird beetles which are important natural enemies of a wide range of cotton pests including and not limited to aphids, thrips and mites.

Table 6 Treatment means showing the efficacy of Tihan OD 175 against ladybird beetles

Treatment	Rate/ha	Pre-treatment	Weeks after 1st Pesticide application						
		0	3	4	5	6	7	Pooled Means ($\sqrt{x+0.5}$)	beetles / plant (x)
		Square root (x+0.5)							
Tihan OD 175	0.15 L	0.71a	1.09a	1.18ab	0.84a	0.93a	0.84b	1.01b	**0.52**
Tihan OD 175	0.20 L	1.06a	1.15a	0.84b	0.84a	0.84a	0.71b	0.89b	**0.29**
Tihan OD 175	0.25 L	0.71a	0.84a	0.84b	0.84a	1.18a	0.71b	1.08ab	**0.67**
Thunder 145 OD	0.30 L	0.71a	0.71a	0.84b	0.97a	1.06a	0.71b	0.97b	**0.44**
Untreted control	-	0.97a	1.18a	1.59a	0.93a	1.28a	1.22a	1.32a	**1.24**
LSD (p=0.05)	**-**	0.35	0.48	0.66	0.46	0.79	0.17	0.26	
P-Value	**-**	0.132	0.203	0.107	0.956	0.751	**<0.0001**	0.015	
CV (%)	**-**	27.84	32.16	41.48	34.84	49.31	13.62	45.78	

Means in the same column followed by the same letter are not significantly different by LSD test at p=0.05 level

Note: x=Number of beetles/plant

4.7 Plant biomass, life plants, damage score, total seed cotton and percentage (% BR)

Table 7 show the Biomass of cotton plants taken at harvest. Results presented show significantly, low biomass 7.00 kg per plot in Thunder 145 OD and significantly high Biomas in plots treated with Tihan 175 OD at 0.15, 0.20 and 0.25 L ha^{-1} and the control with 11.00, 11.25, 12.25 and 10.25 kg/plot respectively.

In reference to damage, the highest score was recorded in plots treated with Thunder 145 OD at 0.30 L ha^{1} while significantly low mealybug damage score was recorded in plots treated with Tihan 175 OD at 0.20 and 0.25 L ha^{-1} with each recording a score of 0.25 while slightly higher damage score were recorded in Tihan 175 OD at 0.15 L ha^{-1} and the untreated control with a score of 1.50 and 1.25 respectively.

Results presented in Table 11 show that there was no significant difference in the number of bolls per plant, total seed cotton yield and the weight of grade BR seed cotton between all the treatments.

Table 7: Treatment means showing effect of Tihan OD 175 on mealybug damage, Yield and quality of seedcotton

Treatment	Rate/ha	Boll/plant	Seedcotton (kg/ha)	Wt of BR
Tihan OD 175	0.15 L	57.5a	1298.8a	63.8a
Tihan OD 175	0.20 L	50.3a	1171.7a	35.5a
Tihan OD 175	0.25 L	41.8a	1171.2a	47.8a
Thunder 145 OD	0.30 L	52.5a	1342.5a	24.5a
Untreted control	-	44.3a	1145a	35.0a
LSD (p=0.05)	**-**	42.98	1318.4	53.06
P-Value	**-**	0.936	0.602	0.587
CV (%)	**-**	57.5a	50.02	43.75a

Means in the same column followed by the same letter are not significantly different by LSD test at p=0.05 level

CONCLUSION

The results obtained in the current study show that Tihan 175 OD at the rate of 0.20 - 0.25 L ha^{-1} in 500 litre of water is effective against the cotton aphids, African bollworm and the cotton mealybug. The findings of the study also reveal that the application of Thunder 145 OD at 0.30 L ha^{-1} encouraged the build up of the cotton mealybug. The use of Thunder in the control of mealybugs is highly discouraged. Tihan 175 OD at 0.20 - 0.25 L ha^{-1} was found to be effective in the managent of cotton aphids, African bollworm and the cotton mealybug. Tihan 175 OD at the rate of 0.20 - 0.25 L ha^{-1} was found to conserve the natural enemies namely ladybird bettles and attendant ants in cotton fields.

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7.Parallel Session 6: Crop Management, Biotechnology and Climate Change

7.1 Physicochemical characterization of selected rice (*Oryza sativa* L.) Genotypes based on gel consistency and alkali digestion

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ABSTRACT

Knowledge of rice genetic diversity is necessary to ascertain the germplasm conservation and the development of improved rice genotypes with good quality traits through various breeding programs. Blending of rice with good and poor quality traits by unscrupulous traders in order to make enormous profits causes a negative impact on the consumer preference and the rice trade. Genetic diversity was determined using the 8 SSR markers that are tightly linked to the quantitative trait loci's (QTLs). Minitab 17.0 software package was used to analyse the gel consistency test results while the alkali digestion values were determined using standard evaluation system by International Rice Research Institute. PowerMarker version 3.25 was used to determine allele number, gene diversity and the polymorphic information content (PIC). GenAlEx version 6.41 was used to determine the principal coordinate analysis (PCoA) and analysis of molecular variance (AMOVA). DARwin 6.0.12 statistical software was used to determine Jaccards genetic dissimilarity matrix and unweighted neighbour joining tree. The rice genotypes were classified into low, intermediate and high alkali digestion values and also soft, hard and intermediate gel consistency. The number of alleles per locus ranged from 2 to 4 with an average of 2.75. Polymorphic information content (PIC) ranged from 0.5224 (RM577) to 0.1411 (RM85) with an average of 0.3673. Gene diversity ranged from 0.5764 (RM577) to 0.1528 (RM85) with an average of 0.4181 with one rare allele was detected at RM577 loci. Genetic dissimilarity ranged from 0.9333 to 0.1818 with the least being observed between *IR 54* and *BS 370* while the highest, 0.9333 between *Saro 5* and *IR 2793*. Unweighted neighbour joining tree showed three major clusters and subsequent sub-clusters hence effectively differentiating the Kenyan and Tanzanian genotypes based on gel consistency and alkali digestion. Clustering was complemented with the findings in the principal coordinate analysis.

INTRODUCTION

Rice (*Oryza sativa* L.) is a monocotyledonous plant belonging to the grass family (Gramineae) and the genus *Oryza*. Rice is the major staple food for the 57% of the world's population and it provides approximately 23% of daily caloric intake. It was introduced into Kenya in 1907 from Asia and is an important cereal crop after maize and wheat in the country (1, 2). The quality preferences of rice consumers have resulted in a wide diversity of the rice genotypes specific to different localities. The physicochemical properties comprises of gel consistency (GC), alkali digestion, and amylose content (3). Gel consistency is used in distinguishing cooked rice texture of high amylose genotypes. Genotypes are grouped based on the gel lengths into; hard (< 40 mm), medium (41–60mm), and soft (>61 mm) (7). The gene coding for gel consistency is located within the *Wx* locus (4, 5). Rice with hard gel consistency hardens faster than genotypes with soft gel consistency. Alkali digestion and gelatinization temperature have a significant correlation. Both traits are controlled by *alk* locus, which encodes *soluble starch synthase* (*SSII*). The use of DNA markers is widespread among plant geneticists because of the substantial amount of useful information that can be gathered from these markers. Simple sequence repeats (SSR) markers have been applied in various studies to study rice genetic diversity, marker assisted selection and in mapping of the QTLs (6,7,8).

MATERIALS AND METHODS

Plant material

A total of 500g of the rice grains of twelve selected Kenyan and Tanzanian rice genotypes were collected from two repositories; Mwea Irrigation and Agricultural Development (MIAD) in Mwea, Kirinyaga county, Kenya and Kilimanjaro Agricultural Training Centre (KATC) in Moshi, Tanzania. Samples were brought to Kenyatta University Plant Transformation Laboratory for molecular analysis. *IR 64* was selected as a model genotype due to desirable combination of attributes such as the intermediate alkali digestion values, amylose content, and soft gel consistency (9).

Molecular and physicochemical methods used

Alkali digestion was determined using methodology described by (10). Gel consistency in rice genotypes was determined using protocol described by (11). Genomic DNA was extracted from leaf samples using cetyltrimethyl ammonium bromide (CTAB) extraction protocol method. SSR markers identified from available Gramene database (http://www.gramene.org). The PCR reactions were was carried out in 200 µl thin-walled PCR tubes in a thermal cycler (Applied Biosystem® 2720). Electrophoresis was carried for the PCR products in 2% agarose gel alongside 3µl 100bp DNA ladder.

RESULTS

Alkali digestion

Based on the degree of alkali digestion observed, the rice genotypes were classified into three groups; low, intermediate and high alkali digestion values. Genotype with low degree of alkali digestion value was *Red Afaa* while four genotypes had intermediate alkali digestion namely; IR *2793, BS 217, BS 370* and *IR 64*. High alkali digestion was observed in 7 genotypes; *Saro 5* and *BW 196* had an alkali digestion value of 6.0 while *Wahiwahi, ITA 310*, *IR 54*, *Kahogo* and *Kilombero* had an alkali digestion value of 7.0 (Table 1).

Gel consistency (GC)

Based on GC values shown in Table 4, the average GC values ranged from 31.50 mm in *ITA 310* to 99.5 mm in *IR 2793*. Genotype *BS 217* had the second highest GC values after *IR 2793* with no significant differences amongst their mean values. There was significant difference between genotypes as shown in Table 2below.

Assessment of SSR profiles

A total of 22 alleles were detected at the loci of the 8 SSR markers across the 12 genotypes. The number of alleles per locus ranged from 2 in RM 341, RM 539 and RM 85 to 4 in RM 577, with an average of 2.750. The highest gene diversity was observed in RM577 at 0.5764, while RM85 had the lowest gene diversity of 0.1528 with an average of 0.4181. Polymorphic information content (PIC) showed an average of 0.3673 with RM577 showing the highest PIC value (0.5224) and RM85 showing the lowest values of 0.1411 (Table 3). A rare allele was observed in Marker RM 577 loci at 400bp (Table 3; Figure 1).

Genetic dissimilarity

A dissimilarity matrix based on the Jaccard's dissimilarity index was used to determine the levels of relatedness of the 12 rice genotypes based on gel consistency and alkali digestion. The genetic dissimilarity ranged from 0.9333 to 0.1818. *Saro 5* and I*R 2793* had the highest genetic distance of 0.9333 while *IR 54* and *BS 370* had the least genetic distance of 0.1818 (Table 4).

Clustering of rice genotypes

Rice genotypes were clustered into major clusters and subsequent sub-clusters. Bootstrap values showed the confidence limits of the phylogenetic branches, where the sub cluster IIB and sub cluster IIA1 had the highest bootstrap value at 56%. The lowest bootstrap value of 19% was attained in major cluster II (Figure 2)

Analysis of molecular variance (AMOVA)

From the total variation, 96% (P<0.001) of variation was distributed within population while 4% (P<0.001) was distributed among populations (Table 3 below)

Principal coordinate analysis (PCoA)

The two dimensional plot shows that the first principal coordinate accounts for 29.43% of the total variation while the second coordinate accounts for 19.84% of the total variation. Genotypes were distributed in all the 4 quadrants (Figure 3 below).

Tables and figures

Table 1. Degree of degradation, alkali digestion values of the 12 genotypes

Genotype	Degree of degradation	Alkali digestion value (ADV)
IR 2793	Intermediate	4.0
BS 217	Intermediate	5.0
BS 370	Intermediate	5.0
BW 196	High	6.0
ITA 310	High	7.0
Saro 5	High	6.0
IR 64	Intermediate	4.0
Kilombero	High	7.0
Red Afaa	Low	1.0
Kahogo	High	7.0
IR 54	High	7.0
Wahiwahi	High	7.0

Table 2. Analysis of variance of the gel consistency values of the 12 rice genotypes

Genotype	Gel consistency values (mm)
IR 2793	99.50 ± 0.50^{a}
BS 217	97.00 ± 1.29^{ab}
BS 370	75.25 ± 3.90^{bcd}
BW 196	67.00 ± 3.39^{cd}
ITA 310	31.50 ± 4.48^{e}
Saro 5	66.50 ± 3.48^{cd}
IR 64	67.75 ± 3.42^{cd}
Kilombero	69.50 ± 3.07^{cd}
Red Afaa	78.50 ± 9.54^{abc}
Kahogo	67.50 ± 5.50^{cd}
IR 54	53.25 ± 7.09^{de}
Wahiwahi	54.25 ± 3.33^{de}

Gel consistency values are expressed as Mean ± SEM. Values followed by same superscript letter are not significant different at P ≥ 0.5.One-way ANOVA followed by Tukey's test.

Table 3. Genetic diversity profiles of 8 SSR markers used in the study

Marker	Major allele frequency	Allele number	Gene diversity	PIC
RM333	0.6667	3.000	0.4861	0.4235
RM314	0.7500	2.000	0.3194	0.2545
RM577	0.5417	4.000	0.5764	0.5224
RM501	0.6111	3.000	0.5093	0.4552
RM50	0.5833	3.000	0.5370	0.4694
RM539	0.8333	2.000	0.2639	0.2229
RM347	0.6667	3.000	0.5000	0.4491
RM85	0.9167	2.000	0.1528	0.1411
Mean	**0.6962**	**2.750**	**0.4181**	**0.3673**

Table 4. Jaccard's coefficient genetic dissimilarity matrix of the 12 genotypes

Genotypes	*IR 2793*	*BS 217*	*BS 370*	*BW 196*	*ITA 310*	*IR 64*	*IR 54*	*Saro 5*	*Kilombero*	*Red Afaa*	*Kahogo*
BS 217	0.7273										
BS 370	0.6923	0.3333									
BW 196	0.5385	0.5833	0.4615								
ITA 310	0.6364	0.7000	0.5455	0.6154							
IR 64	0.6364	0.8182	0.6667	0.8750	0.6000						
IR 54	0.7333	0.4545	0.1818	0.5333	0.6154	0.7143					
Saro 5	0.9333	0.8333	0.5833	0.8125	0.7500	0.6364	0.6429				
Kilombero	0.5385	0.5833	0.5714	0.5333	0.5000	0.6154	0.5333	0.8824			
Red Afaa	0.6000	0.7333	0.6250	0.5000	0.5714	0.6667	0.5882	0.8333	0.2857		
Kahogo	0.6000	0.7333	0.6250	0.5000	0.4615	0.6667	0.5000	0.8333	0.2857	0.2667	
Wahiwahi	0.6154	0.6667	0.6429	0.5000	0.8667	0.7857	0.5000	0.8750	0.5000	0.4667	0.4667

Table 5. Summary of analysis of molecular variance (AMOVA)

Source of variation	Df	SS	MSD	Estimated Variation	% variation	P-Value
Among Populations	2	9.667	4.833	0.193	4%	
Within Populations	9	37.000	4.111	4.111	96%	
Total	11	46.667		4.304	100%	<0.001

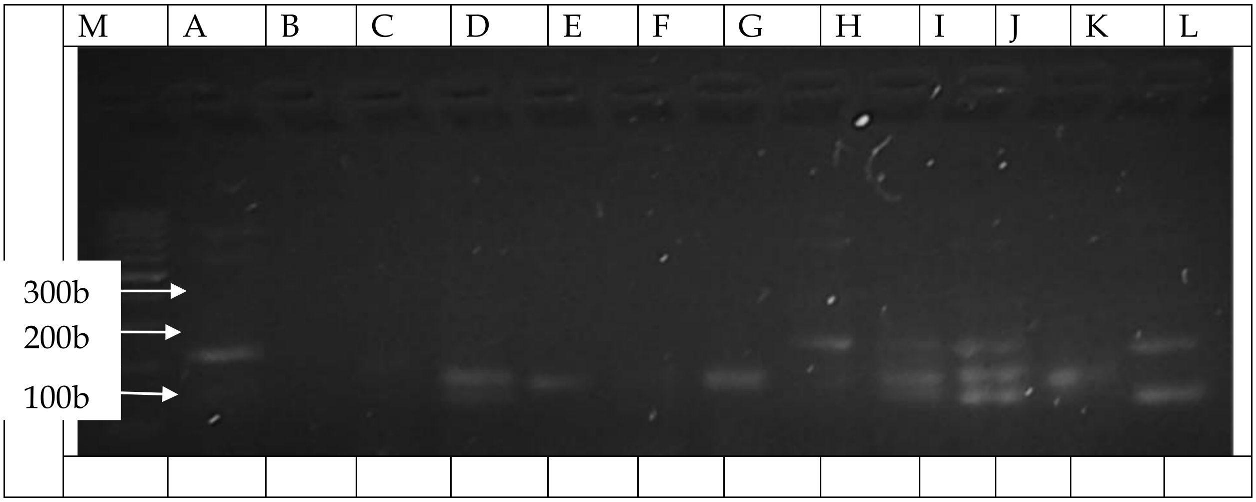

Figure 1. SSR marker RM 501 showing polymorphism pattern of the 12 rice genotypes in 2% agarose gel. A - IR 2793, B - BS 217, C - BS 370, D - BW 196, E - ITA 310, F - Saro 5, G - IR 64, H - Kilombero, I - Red Afaa, J - Kahogo, K -IR 54, L – Wahiwahi. M- 100bp molecular ladder.

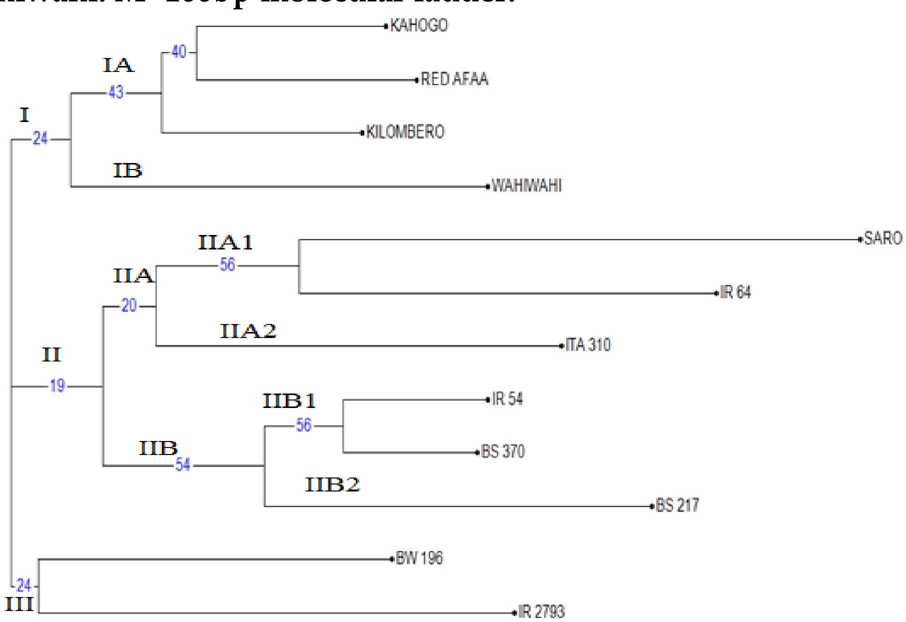

Figure 2. Unweighted neighbour joining dendrogram of the 12 rice genotypes based on gel consistency and alkali digestion using 8 SSR markers.

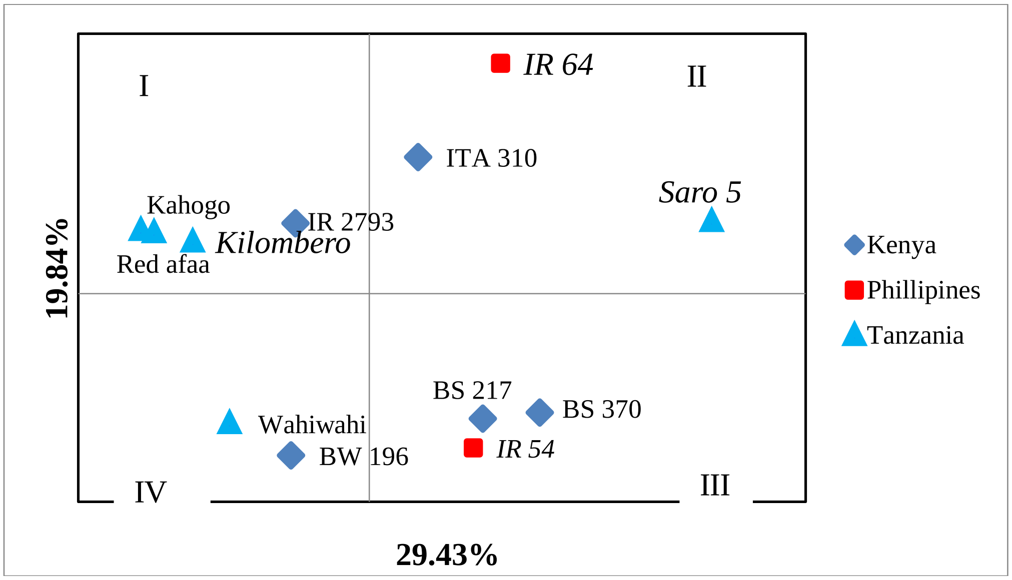

Figure 3. Principal coordinate analysis of the 12 rice genotypes

DISCUSSION

Hard gel consistency observed in this study was due to formation of rigid rice gels, which occur as a result association of starch polymers in the aqueous phase. Amylose polymers leach when the starch granules are heated and they subsequently form networks once the gel cools (12,13,14). Physicochemical characterization of double haploid rice population also reported on the same classification (14). The intermediate gel consistency observed in this study could be due to effects of minor genes, for instance, gene interaction between *waxy* and *pullulanase* or *waxy* and *BEIII* genes (14).

The rice grains that were highly affected by alkali solution had a high ADV. This observation could be attributed to the presence of amylopectin with a high number of short chains (A and B1) with minimal number of long amylopectin chains. Genotypes that were least affected by the alkali solution had a low ADV, which could be attributed to the presence of more long amylopectin chains (B2 and B3) than the short (A and B1) amylopectin chains (14). The intermediate alkali digestion could be attributed to the presence of intermediate number of both the long and the short chains. The number of alleles per locus detected varied per the marker used. This could be attributed to heterozygosity in the varieties studied. Similar findings have been reported in Pakistan basmati and non-basmati genotypes (27). However, these results were less than what is reported by other studies using different genotypes and SSR markers (28, 29). This could be as a result of use of different rice germplasm accessions and the selection of SSR markers.

Gene diversity also referred to as the expected heterozygosity (He) attained had an average of 0.4181. This value was higher compared to 0.358 reported by (30) and lower than an average of 0.5513 reported in Kenyan and Tanzanian genotypes (16) and 0.68 in

Asian rice accessions (31). Evaluation of gene diversity based on the attributes of the genotypes, showed that improved genotypes had higher gene diversity value of 0.3729 compared 0.3167 of the landrace genotypes. Therefore, the low gene diversity is attributed to presence of a common gene pool amongst the landrace varieties unlike the improved genotypes where new genes have been introduced during crop improvement programs. The difference in gene diversity attained in this study with those in published literature could be attributed to the use different set of primers and rice genotypes under study. Based on PIC classification, one marker (RM 577) was the most informative marker while 5 markers were reasonably informative markers. These informative markers can be utilised in marker assisted selection due to its ability to distinguish between genotypes. The mean PIC was less than 0.4680 observed by (33) and 0.31 in Indian basmati and non-basmati rice genotypes (34).

The many rare alleles observed in a germplasm indicates that there is a unique source of genetic diversity amongst the genotypes. Presence of rare alleles are important in fingerprinting rice genotypes (36).

The highest dissimilarity observed between genotypes could imply that these genotypes have an uncommon origin. The unweighted neighbour joining dendrogram was used in this study as it produces additive trees and does not assume identical evolutionary rates along its branches. The low bootstrap values attained in some branches could be attributed to the low redundancy in genetic dissimilarity dataset which is indicative of considerable variation within the genotypes (39). Hence, in order to understand the level of genetic variation contributing to the low bootstrap values, AMOVA analysis using the Euclidean distance matrix (40) was conducted within and among populations. The high within population variation in AMOVA table is confirmed by the large values attained in the dissimilarity matrix as well as the low bootstrap values that were obtained for each of the cluster nodes (41). The PCoA showed that genotypes that are located closer to one another have more similarity than those that are ordinated further away.

CONCLUSIONS

From this study, it can be concluded that physicochemical classification showed considerable variation based on gel consistency and alkali digestion. Molecular diversity shows that improved varieties had higher gene diversity compared to landrace genotypes. The PIC values obtained reveals that RM577 is the best marker for diversity studies on gel consistency and alkali digestion given it is highly informative compared to other markers.

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Germplasm Using SSR Markers: An Initiative towards Association Mapping of Agronomic Traits in *Oryza sativa*. *Rice*, *8*(1), 1-25.

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7.2 Impact of nitrogen fertilizer application on groundwater nitrate and ammonium concentration in different farm systems in Ainabkoi, Uasin Gishu County. Kenya.

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ABSTRACT

Excessive nitrogen fertilizer application and its mobility as nitrates (NO_3-N) and ammonium (NH_4-N) down the soil profile makes it the major contributor of non-point source pollution of groundwater. Nitrogen pollution of groundwater in Uasin Gishu is of particular concern because it is a high-potential maize agro-ecological zone, has high levels of fertilizer consumption and the dosage rates seem to be increasing. The objective of the study was to assess the potential risk of fertilizer application on ammonium and nitrate contamination of groundwater in different farms systems. Farm were purposively stratified into three non-overlapping strata (location) Ainabkoi, (large >40 acres), Kispinende (medium 10-40 acres) and Olare (small 2-10acres) mixed farm systems and well water evaluated in a longitudinal and diagnostic study. Fertilizer application rates at planting ranged 22 – 44 Kg N /Ha and at top dressing 32-48 Kg N/ha CAN (26%). Groundwater NH_4-N and NO_3-N concentrations ranged from of 1.85-542.38µg/l and 1.61-246.18 µg/l respectively. There were no significant differences in the ammonium and nitrate concentrations between the farms, but the highest concentrations were found in wells within the large farm systems. There were positive linear relationships between N fertilizer and NH_4-N ($Y = 0.586x + 55.729$ $R^2 = 0.27$) and NO_3-N ($Y = 3.74x - 463.99$ $R^2 = 0.31$) groundwater concentration at topdressing. Therefore timing of N fertilizer application is a critical aspect in determining the potential to pollute groundwater.

Keywords: Groundwater, Farm Systems, Nitrogen Fertilizers, Ammonium-nitrogen, Nitrate-nitrogen

INTRODUCTION

Throughout history the increase and intensive use of nitrogen-based fertilizers to achieve higher yields or productivity in agricultural systems has been well documented in Japan (Kumazawa, 2002 and Inoue et al., 2012), in China (Liu et al., 2005; Liu et al., 2005 and Ju et al., 2006), USA (Kraft, G.J. and Stites, W. 2003), Australia (Keating et al. 1996) and New Zealand (McLay, et al., 2001). It is accepted that the use of fertilizer nitrogen is expanding globally in order to meet the needs for food, fibre, and fuel of a growing world population (Zhang et al., 1996 and Snyder et al, 2009). Nitrate contamination of groundwater usually exceeds the standard for drinking water in the regions where N fertilizer application rates are above 500 N ha^{-1} and N use efficiency is less than 40% (Zhang et al, 1996).

The main diffuse source of nitrates in groundwater has been identified as nonpoint source from excessive use of nitrogen based fertilizers in agricultural and livestock production systems (Novotny and Chesters, 1981, Spalding and Exner, 1993, Hill, 1996, Kumazawa, 2002 and Ju et al., 2006). In addition, large one-off applications of soluble fertilizer in excess of immediate crop needs can lead to substantial nutrient losses leaching (Crush *et al* 1997). This is because nitrates are soluble, highly mobile and loosely bound therefore leach out of the soil with percolating water making it unavailable for plant uptake. When N fertilizer application rates exceed the plant demand and the denitrification capacity of the soil, the nitrogen leaches out into groundwater usually as nitrate-N (Lord and Anthony, 2002 and Schroeder et al., 2004). According to Daberkow et al., (2001) the recommended N fertilizer rate is usually based on the amount of N required to meet the expected yield minus the amount of nitrogen in the soil, irrigation water and previous legume crop.

The impact of fertilizer on groundwater has been witnessed in China which has had a strongly increasing trend towards the growth of crops of high economic value mainly vegetables and fruits over the last twenty years (Ju, et al 2006). Nitrogen fertilizer consumption has increased in China and is the main cause of increase in nitrate content in groundwater. The annual fertilizer application has risen gradually from 2.4 kg/HA in the 1950s' through to 211 N kg/Ha in the 1990's in order to meet increasing food requirement by an ever increasing population and reducing arable land (Zhang et al., 1996). A study in Shandong province found that the average N fertilizer rate was 280 kg N ha^{-1} in winter wheat fields, 280 kg N ha^{-1} in maize fields, 1700 kg N ha^{-1} per crop in protected vegetable fields (plastic film greenhouses) and 848 kg N ha^{-1} in apple orchards (Ma, 1999). Townsend et al. (1996) reported high nitrate-N concentrations ranging between 12-60mg N L^{-1} in groundwater in Kansas caused by high application rates of N fertilizer to sugar beet fields. In the Chinese provinces of Beijing, Tianjin, Hebei, Shandong and Shanxi about 45% of 600 groundwater samples exceeded the WHO and European limit for nitrate in drinking water of 11.3 mg NO_3-N (50 mg NO_3^{-1} L^{-1}), with the highest nitrate-N concentration reaching 11.3 mg L^{-1} (Zhang et al., 2004). The human health risk associated with consumption of water containing nitrate is due to the reduction of nitrate to nitrite in the human gut which causes methaemoglobinaemia or 'blue-baby' in infants and stomach cancers in adults (Spalding and Exner 1993, Hudak 1999, EPA 2002, (Lord and Anthony, 2002, Schroeder et al., 2004 and WHO, 2008).

The general or broad fertilizer application rates for maize in Uasin Gishu county, Kenya is about 52-70 kg of DAP per acre at planting and 58 kg of CAN or 92 kg ASN per acre at top dressing depending on the soil fertility. In Kenya the fertilizer dose rates applied on maize fields during the main season has increased from 65 kg/acre in 1997 to 75 kg/acre in 2007 (Ariga *et al*., 2008) and the intensity of fertilizer application has increased dramatically on the intercropped fields. The planting season begins in the month of February. Farmers normally broadcast Di-ammonium Phosphate (DAP 18%) fertilizer at the rate of one 50 kg DAP bag /Acre, equivalent to 9 kg N/Acre (22 kg N/ha) during the last field harrowing procedure. Maize planting was done between March-April in 2012 and 2013 at the onset of the long rains. Top dressing was done when the crop was knee high or 45-60cm high, with Calcium Ammonium Nitrate (CAN 26%) at the rate of one 50 kg CAN bag /Acre equivalent to 13 kg N/Acre (32 Kg N/ha) as recommended by the Agriculture Extension officers. However it was observed that farmers tended to increase the recommended rate by 1½ to 2 times with the aim of increasing crop yields.

Therefore excessive N fertilizer application is very common and may cause groundwater pollution. The focus today is worldwide is on sustainable agriculture which aims at developing environmentally friendly, ecologically sound and economically profitable agricultural management systems. This means that fertilizer management practices must be geared towards achieving high yields and high-quality crops with the efficient use of water, fertilizers, agrochemicals and energy with minimal environmental impact.

The recommended threshold or maximum allowable concentration (MAC) by WHO and Government of Kenya (GOK) for nitrate-nitrogen in drinking water is 10 mg/l NO_3-N (US EPA, 2000, WHO, 2008) and for Ammonium-Nitrogen is 0.5 mg/L NH_4^+-N (GOK, 2006). To evaluate/access and compare the nitrogen loading and groundwater nitrate, nitrite and ammonium accumulation in different farm systems in Ainabkoi Sub-County of Uasin Gishu County, Kenya.

METHODOLOGY

The study was carried out in Uasin Gishu County which lies between longitudes 34^0 50´ East and 35^0 37´ West, and latitudes 0^0 03´South and 0^0 55´ North covering a total area coverage of the county is 3,345.2 km^2 (UGCIDP, 2013 and UGDP, 1997). Ainaibkoi sub-county is considered an intensive and extensive agricultural area (Jaetzold and Schmidt, 1983). The main crops produced in the small farm sectors include maize, beans, wheat, vegetables, pyrethrum and flowers and livestock production. It is in the upper highlands zones 1 and 2 (UH1 and UH2), with a very long cropping season and intermediate rains which can be divided in to two variable cropping seasons.

Purposive stratified random sampling technique was applied in selection of the representative farms that had access to a well within the farm or a centrally communal well, for evaluation of the groundwater sources. Each location was considered as a stratum of homogenous farms such that farms in Ainabkoi location were mainly large, family-generations-owned mixed farm systems and ranged more than 40 acres in size (>40 acres). In Kipsinende location farms were medium sized (10-40 acres) mixed farm system with privately owned wells while in Olare the mixed farm system were ranged from 2-10 acres in size with communally owned wells in Olare. A combination of: longitudinal survey, observational/descriptive and diagnostic study designs were used to evaluate the groundwater wells at different times throughout the crop production cycle over a period of two years (2011-2013). Farm systems, as defined by Garrity et al., (2012) are individual farms, with their own specific characteristics arising from variations in resource endowments and family circumstances which are translated into productive activities, and household consumption and decision making activities.

Groundwater samples were collected at least every week from just before planting, in January to March, during planting in April and through to two weeks after topdressing in June-July and thereafter at least once a month until after harvesting in October December in 2012 and 2013. Sampling of groundwater was also done at least once a month during off production season in the months of November to January in 2013. Nitrate-nitrogen (NO_3-N) and ammonium-nitrogen (NH_4-N) were quantitatively determined by methods described in APHA, 1995**.**

The primary data were summarized, organized and presented using the descriptive statistics, table means and graphs. Regression analysis was done by using the SAS software package (Version 6.12, 1997; SAS Institute, Inc., Cary, NC, USA).

RESULTS AND DISCUSSIONS

Maize production is the most important agronomic crop in Ainabkoi sub-county. The Agricultural Extension officers and Kenya seed company recommend fertilizer application rates for the region at 123.56 kg DAP/Ha (22.24 kg N/ha) at planting and 123.56-185 kg/ha CAN (26%) (32.12-48.2 kg N/ha) at topdressing. However, some farmers apply one and a half to twice the recommended rate of DAP and CAN. This results in the application of 185.33-247.11 Kg DAP/ha (33.36-44.48kg N/ha) at planting and 185.33 kg CAN/ha (32.12 kg N/ha) at topdressing. The amount of fertilizer applied as total N (Kg N) in each farm system through the production cycle during planting and at top-dressing during the study period of 2012-2013 is shown in Table 1. This higher application rate was driven by farmer accessibility to higher disposable income that is common with the medium and the large farm systems. The fertilizer application rate in Ainabkoi county closely compares with that of sweet corn production in the state of Illinois, United States (US) which ranges from 84-336 kg N/Ha depending on the soil fertility (Mwanza et al 2011) and in Lithuania where the N fertilization rate for cereals and annual grasses was 90 and 180 kg/ha. Lack of enabling policies for the private industry, poor infrastructure (access to fertilizer), and low demand by fertilizer consumers, especially in rural areas of Sub-Saharan Africa (SSA), are three major causes of low consumption (Ariga et al., 2007).

The total N applied during the maize production season varied significantly with the farm systems because the area under crop production varied in the different farms systems such that the large farm systems had crop acreage ranging from 8-21 ha, the medium sized from 1.2-10.1 ha and the small farm systems ranging from 0.6-2.8 ha during the study period of 2012 and 2013. However, these N-fertilizer rates are much lower than those reported in several parts of the world's farm production areas, such as the average application of N to maize in China of 249 kg N/ha with an application range of 50-600 N/Ha (Cui, 2005).

Farmers in Ainabkoi tend to apply more than the recommended fertilizer rates as is common with many other farmers in other parts of the world. Although the fertilizer recommendation rate for sweet corn was 168 kg N/ha and for potato was 258 kg N/ha in Wisconsin, USA, producers generally apply 250 kg N /ha and 297-357 kg N/ha respectively (Kraft and Stites, 2003) and the groundwater nitrate loading increased with increasing fertilizer. Reports have shown that between 1997 and 2007 fertilizer dose rates applied on maize fields in the area during the main season increased from 65 kg/acre to 75 kg/acre (Ariga *et al*., 2008). At the time of the study the rates had increase to 92 kg N /ha and the farmers express a desire to have more fertile fields through application of more fertilizer. Research has linked the evolution of increasing nitrates in groundwater to increasing fertilizer use in many parts of the agricultural world such as in Central Lithuania (Adomaitis et al., 2008); Vietnam (Kurosawa et al., 2008), China (Ju et al., 2006), Australia (Thorburn, et al., 2003); USA ((Kraft and Stites, 2003; Hallberg et al, 1989), and Japan (Kumazawa, 2002). Several research outputs have also confirmed that groundwater N pollution generally increases with the amount of N-fertilizer application (Jordan and Smith, 2005, Dunn et al., 2005, Liu et al., 2005, Thorburn, 2003, Kuo et al., 2001, Owens et al., 1999, Errebhi et al., 1998, Zhang et al., 1996, and Halberg, 1989). In Central Lithuania, the nitrate concentration in lysimeter water depended mainly on the nitrate fertilizers application rate (Adomaitis et al., 2008), such that fertilization of agricultural crops with 112 kg N/Ha increased nitrate concentration in lysimeter water by 67.1 mg /L to 112.1 mg /L and an N-fertilization rate of 224 kg N /ha increased nitrate concentrations by 139.1 mg/L to 187.2 mg/L. The results from this study did not indicate such large increases in NO_3-N concentration increase with increase in fertilizer nitrogen application due to the fact that fertilizer input levels in Ainabkoi of range of 54-92 Kg N/Ha are still comparatively low.

The groundwater ammonium-N, and nitrate-N concentrations were determined at the time of planting in the months of March and April of 2012 and 2013 (Figure A. B and C). The ammonium-N was generally higher than nitrates-N concentrations in both 2012 and 2013 in the three farms systems. Figures D, E and F show the change in concentration of NH_4-N and NO_3-N in groundwater at the time of top dressing and two weeks thereafter in 2012 and 2013 in the large, medium and small mixed farm systems respectively. The average total amount of N fertilizer applied during top dressing in the large farm systems ranged from 390 N kg to 1053 N kg in 2012 and 2013 which averaged to 598 N kg in 2012 and 657 N kg in 2013. The NH_4-N concentration gradually decreased from June through August. Nitrate concentration in groundwater increased from June through to August in both 2012 and 2013. However in July of 2012 there was a significant increase by 94% in NO_3-N concentration in groundwater. In 2013 the concentration increased by 44% between June and July and then reduced in August.

Analysis did not show a significant positive regression between the N kg/ha applied at planting and the concentration of N-compounds in groundwater in all the three farm systems. However regression analysis at two weeks after top dressing with CAN fertilizer, showed that there were positive linear relationships between fertilizer application at top dressing and NO_3-N concentration ($Y = 3.74x - 463.99$ $R^2 = 0.31$) (Figure G), and NH_4-N concentration ($Y = 0.0586x + 55.729$ $R^2 = 0.27$) in groundwater (Figure H). Therefore this indicates that there is a relationship between the timing of application of fertilizer nitrogen and the loading of N in groundwater. The nitrate-N concentration in groundwater in the different farm systems ranged from a minimum of 0.129 mg/L to a maximum of 0.246 mg/L. These values are less than the maximum allowable concentration of 10 mg/L. Ammonium concentration ranged from 26.43µg/L to 90 µg/L (0.026mg/L to 0.09 mg/L) which was lower than the maximum allowable limit of 0.5 mg/L (500µg/L) in Kenya (GOK, 2006)

According to WHO (1998), nitrate concentration in groundwater is normally low, and can reach high levels due to agricultural runoff and infiltration which was also recorded in the study area. These low values in groundwater nitrate concentration were also recorded in areas of high intensive agriculture in New Zealand where the groundwater nitrate concentration averaged over three years of data collection, ranged from 0.02 mgNO_3-N/ml. Inoue, (2012) reported a linear impact of nitrogen laod from fertilizer on groundwater NO_3-N over a four year period (2000-2004) and attributed the large differential over the regression line to non-fertiliser sources of nitrogen, such as the livestock industry and human sewage. In this research this can be attributed to the same sources of livestock waste, pit latrines and decomposing plant organic matter in the vicinity of the wells.

The NH_4^+ that is relatively immobile but is also carried down the soil profile. The concentration of NH_4-N concentration levels in the groundwater seemed to be higher compared with the levels of NO_3-N. This has also been reported in several studies

(Kurosawa et al., 2008) in farming villages in northern Vietnam (2002-2006), whereby 380-420 Kg N/Ha of inorganic N fertilizer application resulted in high NH_4-N concentration in drinking water and low NO_3-N concentrations (Kurosawa et al., 2008). These results from this study showed that although the N concentration in groundwater did not exceed the recommended maximum concentration, but the application of fertilizer nitrogen has the potential to pollute groundwater systems. This is a common practice in rain fed agriculture in several parts of the country such as Nandi South district tea plantations which is done during the rainy seasons in May and October and causes river eutrophication and nitrate pollution (Maghanga, et al. 2013).
Several studies have reported that the rapid increase in nitrogen fertilizer application in order to achieve higher yields and profits in intensive farming is the main cause of increased nitrate concentration in groundwater such as in Japan (Kumazawa, 2002), in Platte Valley of Nebraska, USA (Daberkow et al., 2001) and in Northern China. (Zhang, et al., (1996).

CONCLUSION

The results from this research showed that none of the wells in Ainabkoi have NH_4-N and NO_3-N concentration in groundwater greater than the Kenya Maximum allowable limits for drinking water of 0.5 mg/l and 10 mg/L respectively. However the variability in N concentrations indicates these wells are vulnerable to impacts of fertilizer N rates and farm systems. The NH_4-N concentration in groundwater was in the range of 3.25-382 µg/l and 1.85-542.38 µg/l in 2012 and 2013 respectively. The highest NH_4-N concentration in groundwater was in wells in the large farm systems with an average of 464 µg/l in 2012 and 2013. The NO_3-N concentration in groundwater was in the range of 1.61-246.18 µg/l and 2.56-177.56 µg/l in 2012 and 2013 respectively. The groundwater NO_3-N concentration was highest in the large farm systems with an average of 211.87 µg/l in 2012 and 2013.
The potential for Ainabkoi farmers to increase the field outputs by improving on their fertilizer application rates exists as farmers chose to shift to horticultural production and increase in N fertilizer application in cereal production. The potential impact of fertilizer nitrogen application on the concentration of nitrate in groundwater brings into perspective the importance of timing and splitting of N fertilizer application. Timing of nitrogen inputs is critical because the concentration of nitrates in the drainage water depends on the balance and timing of nitrogen inputs and outputs to and from the soil and on the rates of nitrification and removal of nitrates from the soil solution (Brady and Weil, 1999). Farmers in Ainabkoi sub-county normally do a one-off application of top dress during the peak rainfall period of the production season, which is usually in July. This exposes the nutrients to runoff and leaching especially nitrogen due to its high solubility.
Notably the, the causal relationship between nitrogen fertiliser and pollution is obscure and uncertain because of the unknown processes of transportation from non-point source to specific monitoring points (Inoue, 2012). This means that most changes occurring on farmland surface cannot be directly related to the concurrent status of

groundwater, but that can be related to past changes on farmland and groundwater flow dilution.

RECOMMENDATION

Agriculture must co-exist with environmental concerns hence there is need to quantify the leaching losses of N from a range of fertiliser practices over several seasons in order to develop environmentally and economical fertilizer application rates. The absence of any significant contamination of groundwater in this study does not preclude it occurring in the future. There is a gradual shift to more intensive agriculture with the production of cut-flowers and vegetables for local and export markets, along with increased N-fertilizer application rates. These are known prerequisite conditions for groundwater pollution. Therefore there is need to advocated for fertilizer management strategies, such as split fertilizer application (pre- and post-emergence) in order to synchronize N supply with crop seasonal demand and soil and plant tissue nutrient analysis before application of N fertilizer

TABLE I: The total amount of inorganic nitrogen fertilizer (KG N) applied in individual farms and total averages in 2012 and 2013.

Farm System	Total Kg N Fertilizer					
	2012			2013		
	Planting	Top-dressing	Total Kg N	Planting	Top-Dressing	Total Kg N
Large Mixed	288	624	**912**	225	487.5	**712.5**
Large Mixed	360	780	**1140**	486	1053	**1539**
Large Mixed	180	390	**570**	198	429	**627**
Average N Kg	**276**	**598**	**874**	**303**	**656.5**	**959.5**
Medium Mixed	27	39	**66**	54	78	**132**
Medium Mixed	90	97.5	**187.5**	108	117	**225**
Medium Mixed	45	65	**110**	63	91	**154**
Medium Mixed	360	390	**750**	450	487.5	**937.5**
Medium Mixed	202.5	292.5	**495**	202.5	292.5	**495**
Average N Kg	**144.9**	**176.7**	**321.7**	**175.5**	**213.2**	**388.7**
Small mixed	27	39	**66**	27	39	**66**
Small mixed	36	52	**88**	27	39	**66**
Small mixed	18	26	**44**	18	26	**44**
Small mixed	13.5	19.5	**33**	22.5	32.5	**55**
Small mixed	63	91	**154**	63	91	**154**
Average N Kg	**31.5**	**45.5**	**77**	**31.5**	**45.5**	**77**

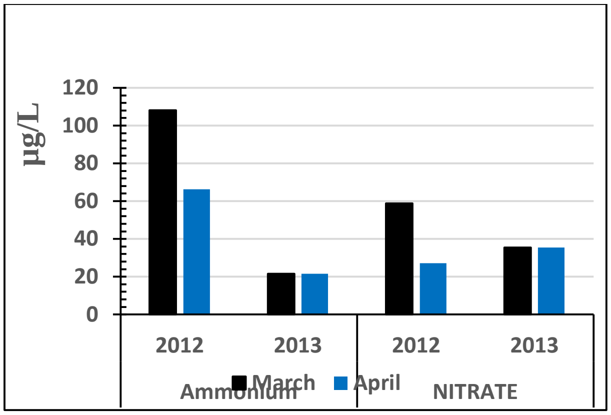

Figure A: Groundwater concentration of nitrogen ions at planting time (March & April) of 2012 and 2013 in the Large Mixed Farm Systems

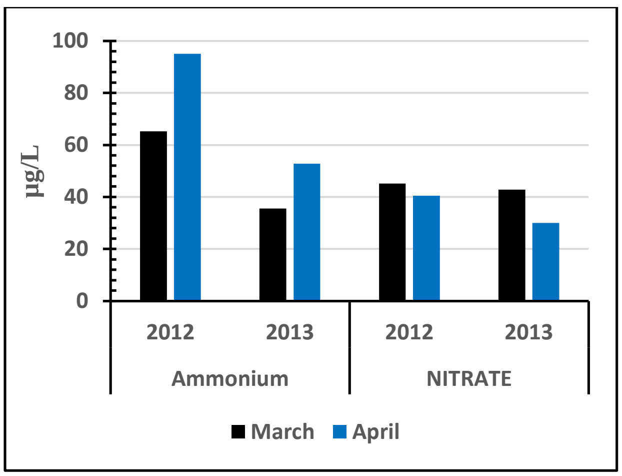

Figure B: Groundwater concentration of nitrogen ions at planting time (March & April) of 2012 and 2013 in the Medium Mixed Farm Systems

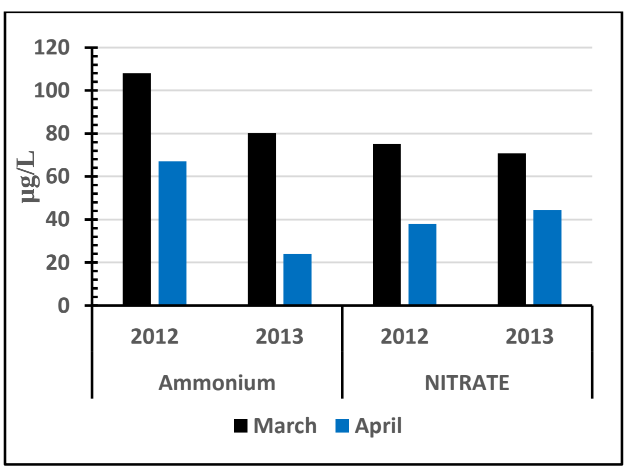

Figure C: Groundwater concentration of nitrogen ions at planting time (March & April) of 2012 and 2013 in the Small Mixed Farm Systems.

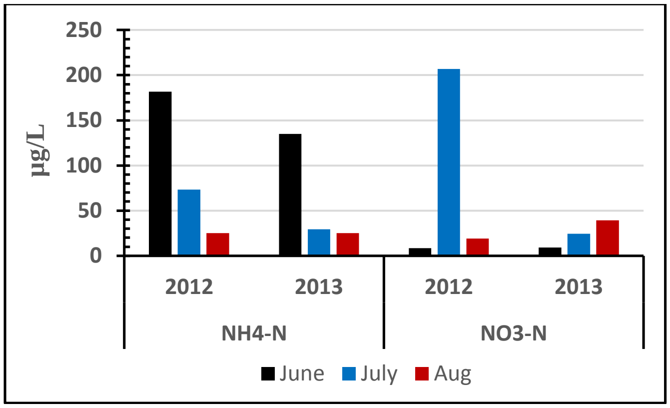

Figure D. Nitrogen concentration in groundwater around the time of top dressing (June, July and August) in the large farm systems in 2012 and 2013.

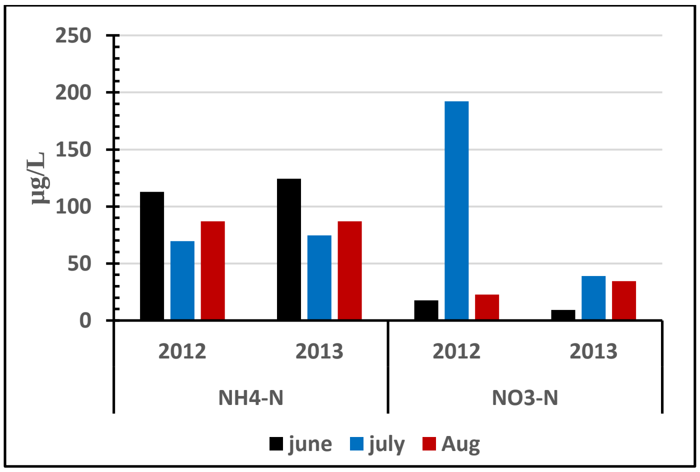

Figure E: Nitrogen concentration in groundwater during top dressing time in the medium Farm systems in 2012 and 2013

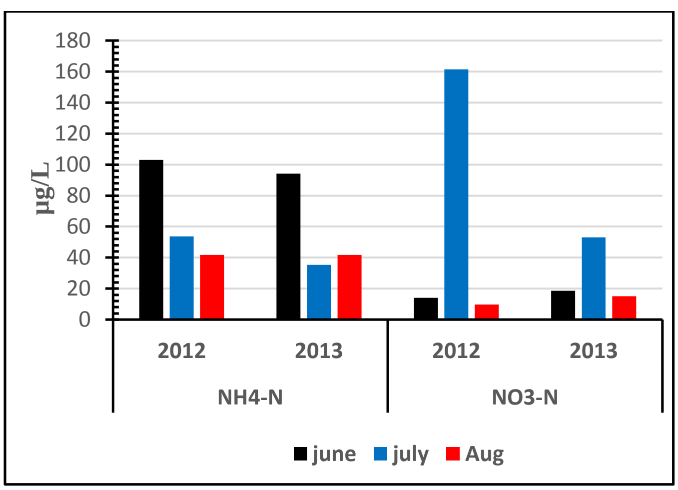

Figure F: Nitrogen concentration in groundwater during top dressing time in the small Farm systems in 2012 and 2013

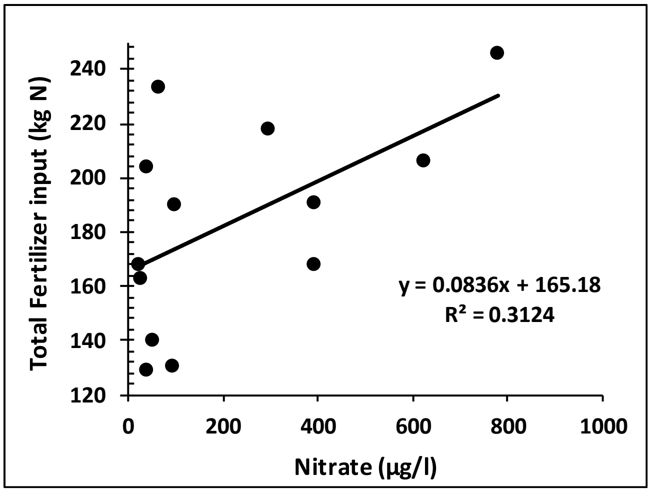

Figure G: Relationship between Nitrate Concentration in groundwater and Fertilizer two weeks after Top Dressing in 2012.

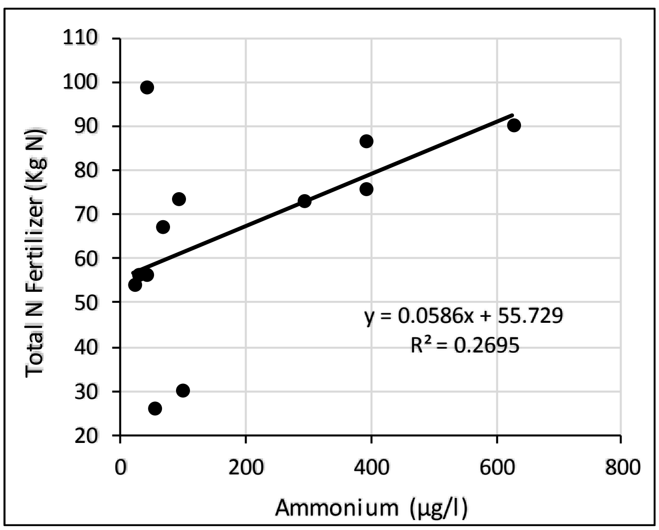

Figure H: Relationship between Ammonium concentration in groundwater and fertilizer Nitrogen two weeks after top dressing in 2012

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7.3 Supplementing households income through sericulture technology.

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ABSTRACT
Sericulture value chain comprises feeding of silkworms for cocoon production and post-cocoon activities for production of silk yarn. The silk industry by its nature is a cluster of many non-farm and on-farm activities and has a strong need for many forward and backward linkages. It is therefore suited as a tool for rural employment and poverty alleviation in populous developing countries. The venture, if embraced in Kenya can be an important catalyzer of economic development for the value chain stakeholders in contributing towards government's strategy to grow the economy by 10% through the agriculture sector. A study was therefore conducted by Kenya National Sericulture Research Centre (NSRC) with an aim to establish the industry's capacity in supplementing household incomes in Kenya. Silkworm farmers and silk processors were sampled from secondary data obtained from NSRC and International Centre of Insect Physiology and Ecology (ICIPE) records for the past ten years. Incomes realized by the farmers were analyzed for comparison with respective projections. It is projected that under ideal conditions, domesticated sericulture in an acre can generate about Ksh.200, 000 from cocoon sales in a year. It was however established that though 40% of the farmers sampled were able to realize these projections, there is huge discrepancies in cocoon productions realized by farmers rearing silkworms in the same

land sizes. To aid the farmers fetch better returns, the NSRC has devised a model where farmers collectively process their cocoons and get higher profit due to economies of scale and enable them remain actors in the sericulture value chain. It was therefore concluded that the sericulture industry has the potential to supplement household incomes in
Kenya. However, proper motivation of farmers through customized monitoring and evaluation as well as adequate training among other measures, are essential facilitators.
Key words; sericulture, farmers, cocoons, silk products, income

INTRODUCTION

The vast sericulture value chain comprises provision of feeding silkworms for cocoon production and post-cocoon activities for production of silk yarn. The silk industry by its nature is a cluster of many non-farm and on-farm activities and has a strong need for many forward and backward linkages. It is therefore suited as a tool for rural employment and poverty alleviation in populous developing countries (JAICAF, 2007 & NSRC Manual, 2008). The venture, if embraced in Kenya can be an important catalyzer of economic development for the smallholder, contributing to the government's strategy to grow the economy by 10% through the agriculture sector (MTP II, 2013-2017). The present global silk production is fluctuating between 70,000 to 90,000 Metric Tonnes and the demand for silk is annually increasing by 5%. These figures are bound to rise even more due to increasing demand for fashionable items as a result of fast changing fashion trends (Shekar and Hardingham, 1995). This scenario opens a window for the rural community in developing world to exploit the potential for silkworm farming for economic advancement.

Silkworm farming is widely unexploited in Africa yet financial prospects are high given the global rising demand for silk items or finished products. However, due to low local silk productivity and products quality, the local market remains unsecured while the international market competitiveness is high (JAICAF, 2007). According to Nyamu et al. (2013), domesticated, bombyx-mori, and wild silkworm rearing are technologies that can be adopted in Kenya to help revamp the fizzling silk spinning and weaving cottage industry through provision of raw material. Given the right support by the government and institutions such as NSRC and ICIPE sericulture industry is highly prospective and can act as a tool for strengthening local economy (Mburu et al., 2013). The raw materials such as fibre and natural dyes produced locally are used in the local spinning, weaving and dyeing cottage industry hence reducing outflow of money. Sericulture by-products which include mulberry leaf products have important health benefits that supplement domestic incomes as well as contribute to the household health wellbeing. Under ideal conditions, domesticated sericulture in an acre can generate at least Ksh. 200,000 from cocoon sales in a year (NSRC manual, 2008). This will have generated employment for approximately 419 man days. To ensure the sector elicits farmers' interests, an outlet for the farmers' products has to be available. Secondary data collected from NSRC and ICIPE, the two major cocoon buyers and silk processors in Kenya, was used to establish the capacity of the sericulture value chain in supplementing households' incomes in

Kenya. NSRC and ICIPE also offer monitoring and evaluation services to the silkworm farmers to ensure optimal returns on the investment.

METHODS

Secondary data from the various sericulture value chain stakeholders collected from NSRC and ICIPE records was used for this study. The period of the data gathered ranged from 2007 to date.

Study Area

The silkworm farmers whose data was used were from Murang'a, Nyeri, Kiambu, Kirinyaga, Meru, Kakamega, Narok, Nakuru, Busia amongst other sericulture practicing counties.

Data Analysis

The data was grouped into the following categories for ease of analysis

2.2.1 Economies of Silk Production in One Acre

Table i gives a summary of the projected financial analysis of silk cocoon production and processing in one acre piece of land.

Assumptions;

When cocoons are dried there is an increase in profit by Ksh. 269,875 (448,189-178,314) in an acre of mulberry from 3rd year.

On processing the dried cocoons, profit increases by Ksh. 80,371 (528,560-448,189) per acre in one year.

Actual Versus Projected Returns of the Silkworm Farmers

Data of 15 sample farmers and the respective land sizes under cocoon production against the dry weight cocoon production from each was given by (ICIPE) for a comparative analysis against the projected productions. Table ii gives the comparative variance between the actual and projected returns of cocoon production in different land sizes.

Assumptions;

Year one profits (Ksh. 55,574) projections were used for ideal income calculations for the different land sizes.

Average Number of worms reared (0.25acre=50,000,0.125acre=30,000), 0.0625=10,000,0.0313=1,000

A scatter plot illustrating the discrepancies of cocoon production in the different land sizes was generated from Table ii as shown in Figure 1. A bar chart illustrating the comparative variance between the actual and projected income from the different sampled land sizes is also shown in Figure 2.

Cocoon Production Versus Income Generated from Various Areas

The data for cocoon production capacity versus the income generated by 23 sampled farmers from various counties in Kenya between years 2007 to 2010 was gathered from

NSRC records for analysis as shown in Table iii. A bar chart representing the data in Table iii was drawn for demonstration as shown in Figure 3.
Market analysis of the various silk products was done based on the data of various buyers as recorded in NSRC from 2007 to date records.
Table iv gives the amount of the various silk products sold by NSRC to processors and merchandisers while Figure 4 gives the respective proportions of each product.

RESULTS AND DISCUSSION

The projected financial analysis of the cocoon production as shown in Table i gives a clear indication of expected ideal returns from cocoon production and/or processing when all factors are held constant. However a significant variation in cocoon output from farmers with same land size under silkworm farming is noted by the wide spread of values around the regression line as shown in the Figure 1 linear scatter plot generated from Table ii. This is further supported statistically by the coefficient of determination that is above 50% (R^2=56.18%) in the same Figure 1. Despite the variations in the cocoon output, it's worthwhile noting that 40% of the sampled 15 silkworm farmers were found to have been able to realize and/or surpass the expected returns as shown in the actual versus expected cocoon output comparative chart in Figure 2, with the assumption that all the sampled farmers reared equal number of silkworms on the same land size. The variations in the cocoon outputs by the sampled farmers could be attributed to insufficient technical knowhow on mulberry management and silkworm rearing practices and capital investment as deduced by a survey conducted by Mburu et al. (2013).
Farmers from Thika County have been found to have produced the highest cocoon output over the years sampled as shown in the Figure 2 comparative bar chart generated from Table iii. This performance can be attributed to favorable weather conditions as well as proximity to the sericulture monitors and evaluators, NSRC in Thika and ICIPE in Nairobi. Kirinyaga, Nanyuki, Meru and Mathioya farmers gave the least cocoon outputs. These discrepancies could have been contributed by harsh weather conditions, given they are all located in cold areas where silkworm rearing is challenging. Figure 4 gives an indication that silk fabric and cocoons have the largest market share respectively. However, the amounts sold are too low, as shown in Table iv, therefore indicating serious challenges in the marketing value chain which could be traced back to low product quality.

TABLES AND FIGURES

1. Table i: Projected silk production and processing financial analysis

Item Description	Cost (Ksh.)		
	Year 1	Year2	Year 3
Cocoon Drying			
Cocoon drier (60kg capacity)	60,000		
Total variable cost (fuel and labor)	8,930	51,180	67,840
Yield (42% fresh weight)	64,504	387,022	516,029
Return (Profit @ Ksh.1097/kg)	55,574	335,842	448,189
Raw Silk Reeling			
Multi end reeling machine (4kg dry cocoons/day: 1.52kg raw silk)	170,000		
Pressurized cooking machine	270,000		
Booking machine	15,000		
Electric skein twisting machine	50,000		
Total	565,000		
Total variable cost(skilled labour)	23,930	139,180	185,840
Yield (Approx. 38% dry cocoons:2.63/kg raw silk)	88,000	536,000	714,400
Income @ Ksh. 4000/kg	34,070	396,820	528,560

2. Table ii: Actual and projected income from cocoon production in different land sizes

Sample Cases	Cocoon production (kg dry weight)	Land size(Acre)	Actual Income (ksh. 500/kg)	Ideal	Variance
Case 1	16.8	0.25	8,400	13894	5494
Case 2	18.9	0.25	9, 450	13894	4444
Case 4	21	0.25	10,500	13894	3394
Case 5	25	0.125	12,500	6947	-5553
Case 6	10	0.125	5,000	6947	1947
Case 7	10	0.125	5,000	6947	1947
Case 8	18	0.125	9,000	6947	-2053
Case 3	8.4	0.0625	4,200	3473	-727
Case 9	5	0.0625	2,500	3473	973
Case 10	0.42	0.0625	210	3473	3263
Case 11	5	0.0625	2,500	3473	973
Case 12	10	0.0625	5,000	3473	-1527
Case 13	2.1	0.0313	1,050	1739	689
Case 14	8	0.0313	4,000	1739	-2261
Case 15	7	0.0313	3,500	1739	-1761

3. Table iii: Different years cocoon production/income of farmers from different counties

Year	County	Cocoon production(dry weight)	Income (Ksh.)
2007	Muranga	8.82	7938
2007	Thika	8.4	7560
2007	Isinya	16.17	14553
2008	Meru	0.42	378
2008	Nanyuki	0.84	756
2008	Nakuru	3.36	3024
2008	Thika	3.36	3024
2008	Taita	0.525	472.5
2008	Mathioya	0.126	113.4
2009	Kirinyaga	0.672	604.8
2009	Narumoru	8.4	7560
2009	Meru	1.26	1512
2009	Laikipia	1.05	945
2009	muranga	4.41	3969
2009	Kijabe	1.68	1512
2009	Ikoloman	4.41	3969
2009	Thika	29.484	26535.6
2009	Karatina	1.47	1323
2010	Kijabe	10.122	9109.8
2010	Meru	5.04	4536
2010	Thika	22.26	20034
2010	Kirinyaga	5.04	4536
2010	Busia	1.47	1323

4. Table iv: Silk products sold

Silk Product	Amount (kgs)
shells	12
Floss	21
Pupa	7
Cocoons	25
Degummed fibre	3
Raw silk	0.43
Fabric (m)	49

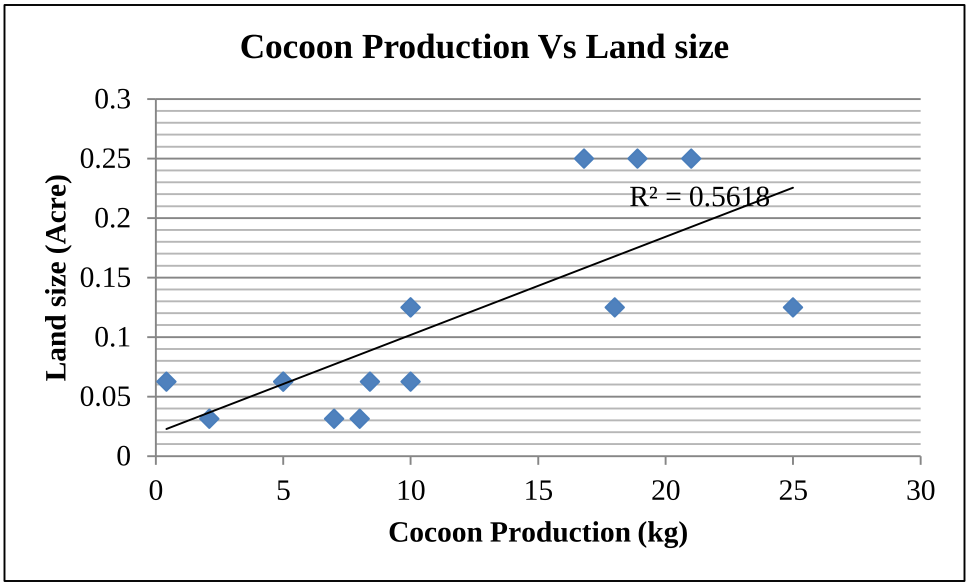

Figure 1: Cocoon production versus land size scatter plot

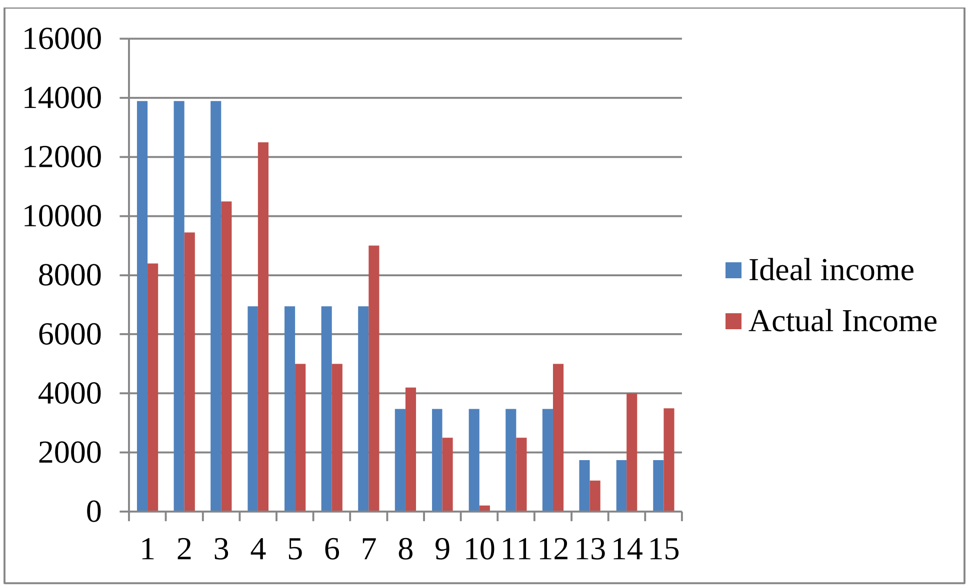

Figure 2: Actual and ideal cocoon production income chart

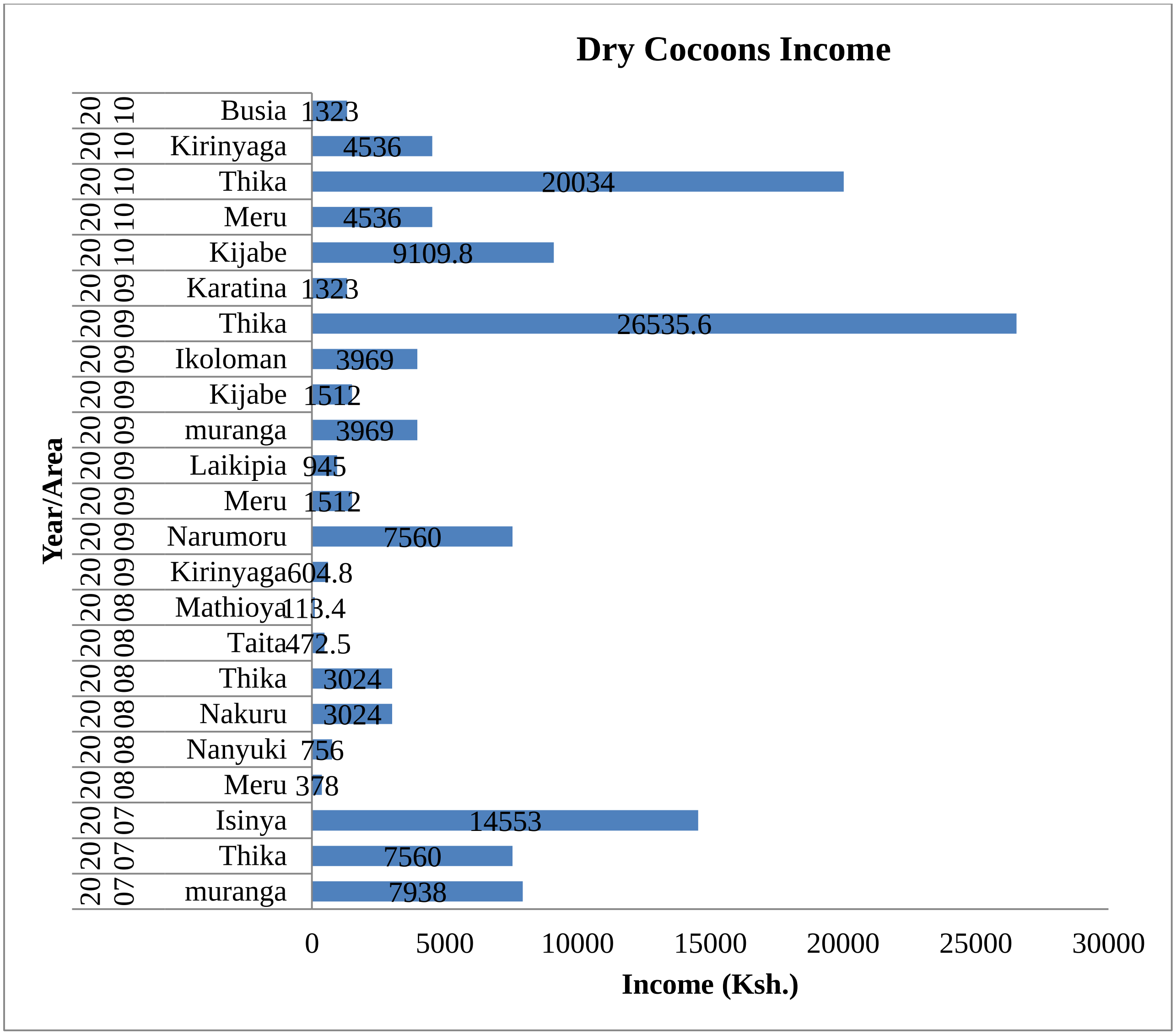

Figure 3: Different farmers/areas dry cocoons income chart

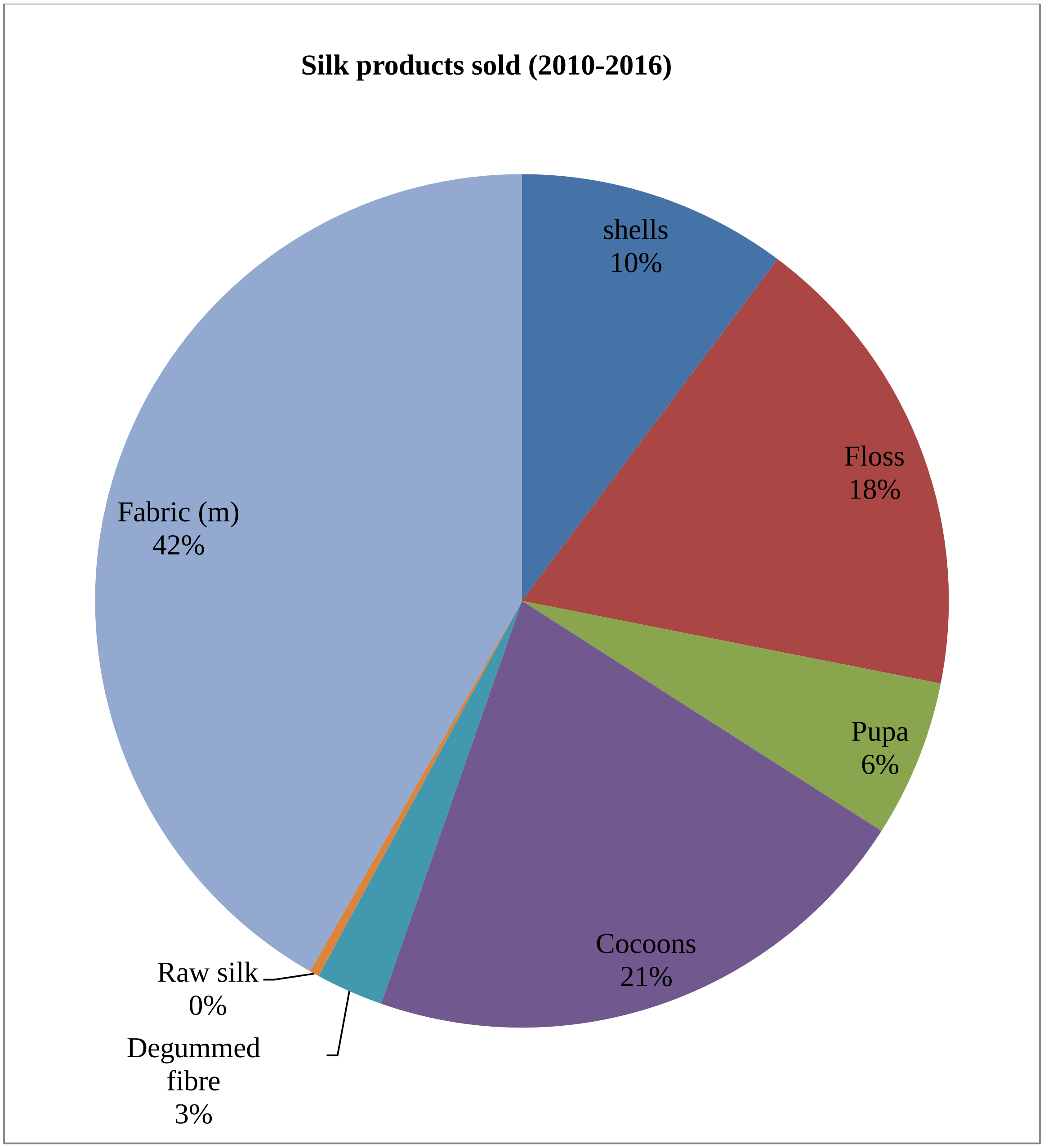

Figure 4: Proportions of silk products sold by NSRC (2007-2016)

CONCLUSION AND RECOMMENDATION

The sericulture industry in Kenya has therefore been found to have the capacity to supplement households' incomes in Kenya as per the projected financial analysis. This has further been supported by the few farmers who have been found to realize these projections. It can therefore be recommended that farmers from different regions in Kenya be given customized attention by the industry monitors and evaluators, ICIPE and NSRC to motivate them realize fully the expected returns and hence supplement their household incomes. The government should also set clear sericulture - specific

policies and strategies that aim at promoting the industry. The processors should also be equipped with the right training on how to produce competitive and adequate products that can easily be absorbed in the market.
To address this, the NSRC has devised a marketing model where farmers collectively process the raw materials and offload products to the market with NSRC assistance. For example, payment to the farmer for their raw material will be based on the quantity and quality of the value added silk fibre. This model will ensure that the farmers get high profit due to economies of scale in processing, making it an incentive for the farmer to remain as an active actor in the sericulture value chain. The center also sells different silk raw materials and products to processors and merchandisers. This enables easier linkage of the silk worm farmers and silk consumers. Silk processors such as weavers will be assured of quality raw materials for advancement of the industry.

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7.4 Seed certification as a means of curbing emerging diseases: A study of Maize Lethal Necrosis disease in Kenya

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ABSTRACT
Maize lethal necrosis disease (MLND) is an important constraint in maize production in sub-Sahara Africa that threatens food security and poses challenge in trade. It was first reported in Kenya in 2011 and has since spread to other countries in the region. The disease is caused by a combination of Sugarcane mosaic virus (SCMV) and Maize chlorotic mottle virus (MCMV), which are vectored by aphids and thrips, respectively. Maize is the main staple food in Kenya and therefore, with the advent of the MLND, there was need to establish mechanisms aimed at combating the spread of the disease. This resulted in the amendment of seed certification protocol which included testing of seed. In consultation with seed stakeholders, KEPHIS incorporated guidelines for MLND inspection in maize seed certification program where all maize seed crops were inspected three times including preliminary, first, second and third inspections. A seed sample was taken before seed dressing for laboratory test to ensure the lot is free from MLND. Imported seeds were also tested for MLND before being accepted into the country. Furthermore, there have been concerted efforts by breeders and researchers to develop and screen maize lines for resistance to MLND. Other strategies that have been put in place include control of vectors and use of certified seed which are free from MLND. Amendments in seed certification program that were implemented in Kenya have led to drastic reduction of MLND. It is further hoped that resistant maize lines from the breeding program will further support the effort to manage the disease.

Keywords: Maize, MLND, Resistance, Screening, Seed certification, seed testing

INTRODUCTION
Maize is the most important cereal crop in both Sub-Saharan Africa and Latin America. It is an important staple food for more than 1.2 billion people in Sub Sahara Africa. All parts of the plant can be used for food and non-food products. In industrialized countries, maize is largely used as livestock feed and as a raw material for industrial products. According to 2007 FAO estimates, 158 million hectares of maize are harvested worldwide of which 29 million hectares are harvested in Africa, with Nigeria, the largest producer in SSA, harvesting 3%, followed by Tanzania. Maize is widely grown in Kenya and ranks highly in food security, meeting dietary preferences of many communities.

Although many production constraints have been reported on Maize, MLND has emerged as an important constraint in maize production in sub-Sahara Africa that threatens food security and poses challenge in trade (FAO June 2013). The disease is caused by a synergistic interaction of Maize Chlorotic Mottle Virus (MCMV) and Sugarcane Mosaic Virus (SCMV) or other cereal viruses like Maize Dwarf Mosaic Virus (MDMV) or Wheat Streak Mosaic Virus (WSMV) (Morales et al 1999) In Kenya, the disease has been reported to be caused by a combination of MCMV and SCMV although the two viruses independently are capable of causing a significant damage. Sugarcane Mosaic Virus has been in Kenya for a long time thus has not been a major threat in maize production. The entry of MCMV in 2011 has been the source of major threat to maize farming (Wangai et al 2012). Maize chlorotic virus (MCMV) is the only established member of the genus Machlomovirus in the family Tombusviridae (Fauquet et al.; 2005) which was first established in maize from Peru (Castillo and Hebert, 1974).

MLND TRANSMISSION.

MLND which is a combination of Sugarcane mosaic virus (SCMV) and Maize chlorotic mottle virus (MCMV),are vectored by aphids and thrips, rootworms and leaf beetles, respectively. Severe infection has been reported in areas where maize is grown continuously due to continuous availability of inoculum. The build-up of vector that transmit the virus is also evident during continuous cropping. MCMV has been reported to survive in maize residues in the field for long (Li et al., 2011). MCMV has also been reported to be either seed-borne where seed produced from infected plant may carry the virus or seed-transmitted. Although a seed transmission rate of 0.3% was been reported (Li et al., 2011; David et al., 2012), the effect is severely amplified when the small inoculum is taken up by vectors in the field. There has been no quantitative assessment of seed transmission of MCMV that has been published recently but evidence in Eastern Africa so far indicate that these virus among others can be carried through seed more so where seed production fields had high incidence of MCMV. A small source of inoculum of the virus in the field either from the seed surface contamination or seed-borne will have a severe effect in the entire field when the vectors takes up the virus and spread the virus in wider areas especially where no proper phytosanitary measures has been established to control the vectors. Whether the virus occurs on the outer surface of the maize seed or inside the maize seed, chances of the virus being transmitted to the new generation of crop in the field stand high (Stanley et al,; 1991).

MLND FREE SEEDS PRODUCTION

In Kenya, a concerted effort was initiated by the government through various institutions including both governmental and non-governmental bodies. Their target was to find ways of curbing the MLND menace that was threatening maize production. The team involved included higher learning institutions, research organizations, Ministry of Agriculture and KEPHIS. Among many strategies that were adopted, disease free seed production was taken up as one of the most viable target to ensure the disease cycle interrupted.. This led to amendments in maize seed field inspections guidelines. MLND was given a higher weight and priority in scoring during inspection with a 0% tolerance level being adopted for field and laboratory stages. Seed dressing with appropriate systemic insecticides was also recommended for the control of vectors. Seed dressing was strategically scheduled to be done after final laboratory results have been released so as to minimize loss where the seed lot is tested and found positive. Such lots were recommended for milling to reduce the losses incurred by the seed companies.. Rejection during field inspection would enable the seed company to make a decision on whether the seed crop could be converted to commercial crop or even the maize could be sold for consumption while still green in the field.

KEPHIS has been utilising these strategies to ensure MLND free seeds are availed to the market for both imported and locally produced seeds. Since as a general rule, the quality of your input ultimately determine the final yield, planting healthy, certified and treated seeds is generally the first step in production of healthy crop. When MCMV virus is introduced through seed to an area where it is has not been previously known to occur, the insect vectors immediately picks up the small inoculum and spread the virus rapidly if the virus is not diagnosed and infected crops rogued in time. In the long run, the virus will establish itself and management at later stages becomes difficult to achieve. In order to curb this menace, KEPHIS has from its mission of ensuring quality agricultural input strived to ensure that all maize seeds passes through rigorous tests to ensure the final quality that will reach the farmers is of high quality and disease free.

The major objective of this work was to ascertain whether the measures that were adopted by KEPHIS through seed certification process are effective. The volumes as well as percentage of rejections at different levels in the certification chain were also established.

MATERIALS AND METHODS

This work has mainly relied on the general operations carried out in KEPHIS especially Nakuru Regional office to curb the spread of MLND. Activities ranging from site selection, seed treatment, field inspections and laboratory testing.. Most of the field activities observed during this study were in Central Rift Valley Kenya. Laboratory samples were taken from both field samples and also from import consignments at the port of entry.

MLND SEED SAMPLING PROCEDURE

Field inspection of maize crop after amendments of seed certification protocol is done three times. For 1 to 2.5 Hectares, 2000 maize plants are counted;. At final level inspection, MLND infected plant is not supposed to be present in the field during inspection. First inspection is done one month after planting, where a tolerance of not more than 1% is accepted but with recommendations for rouging infected plants. Second inspection is done six weeks after planting or two weeks after first inspection.

At this stage, the crop is almost flowering, de-tasseling and off type rouging underway. MLND infection of more than 0.9% is an automatic rejection. Rouging is recommended at this stage. Second inspection rouging is allowed for 0.9% infection and below.
For 3rd and final inspection MLND tolerance is curbed at one per cent although the tolerance percentage is expected to be lowered to zero per cent at this stage. The 3rd and final inspection is done normally one week after 2nd inspection. During this inspection, whenever MLND is spotted in the field under inspection, an outright rejection is done, tolerance is pegged at zero percent.
SAMPLING PROCESS FOR LABORATORY CONFIRMATION FOR MLND.
Each seed crop after harvesting and shelling was sampled for MLND laboratory confirmatory test. For imported maize seeds, a sample was taken at the port of entry where the seeds are held while awaiting the outcome of the laboratory results. For locally produced seeds, immediately after shelling and before transportation, an inspector took a sample using a sampling probe. Labelling of the sample was done by the inspector filling all the sample details in the official KEPHIS SR9 forms before the sample being dispatched to the KEPHIS Molecular laboratory for testing.

LABORATORY DIAGNOSIS OF MLND

KEPHIS has equipped three molecular testing laboratories that carry out MLND diagnosis. These are the Molecular laboratory at Plant quarantine and Biosafety Station, KEPHIS headquarter molecular laboratory and Molecular Testing Laboratory at KEPHIS Nakuru. Official samples are received accompanied by KEPHIS Form SR9 forms which contain all the details of the sample. The information on the Form SR9 is captured in the database and the sample bags are coded with an identity number for use in the laboratory. Usually, 400 hundred seeds per sample are planted in sterile media (Current ISTA Rules 2016) and incubated at 20^0C to 30 ^{0}C for at seven days until the sample is at two leaf stage. The sample is then harvested by cutting the tips of each seedling of the sample into a labelled sample bag for crushing. RNA is extracted from the leaf using modified CTAB method. Positive control, blank (EB), and water are used as control in the process of real time PCR. The primers indicated in Table (i) are used. The results are collected basing on the CT Values of each sample which correspond to viral load in each sample. The laboratory results are communicated back to the merchant and the sampler advising whether to process or reject the seed. The crop rejected in the field depending on the age of the crop is not harvested until other seed crops have been harvested.

RESULTS
Field Rejections Between 2013 and 2016 in Kenya are illustrated in Table (ii).
Real-time PCR laboratory results since the year 2013 are illustrated in Table (iii)

Tables and Figures

Table i Primers for MCMV and SCMV

MCMV-F	**5′ – CCG GTC TAC CCG AGG TAG AAA - 3′**
MCMV-R	5′ – TGG CTC GAA TAG CTC TGGB ATT T- 3′
MCMV-P	5′– CAG CGC GGA CGT AGC GTG GA- 3′
SCMV-F	5′ – CCA GGC CAA CTT GTA ACA AAG C- 3′
SCMV-R	5′ –CAT CAT GTG TGG ATA AAT ACA GTT GAA- 3′
SCMV-P	5′ -– TGT CGT TAA AGG CCC ATG TCC GCA ′

Table ii. Field rejections due to MLND

Number	**Region**	**Area rejected in Ha.**
1	North Rift(Kitale Region)	154.7
2	Central Rift (Nakuru Region)	408
3	Embu	4.5
4	Nairobi	1.9
5	Kisumu	0.0
6	Mombasa (Bura and Taveta)	0.0
Total		569.1

Table iii: Real Time PCR Laboratory Results Since 2013

No.	**Period**	**No. of MLND samples received**	**No. of MLND samples Tested Negative**	**No. of MLND samples Tested Positive**
1	2014	1444	1406	38 (2.6%)
2	2015	2088	2040	48(2.3%)
3	2016	784	776	8 (1.02%)
Total		4316	4222	91 (2.1%)

DISCUSSION
On average, one hectare of maize crop seed can yield up to 2,940Kgs. From the field rejections above, a total of 569Ha of seed crop have so far been rejected. These translate to 1,672, 860Kgs of maize seed crop that was rejected in the field. Normally, for small scale farmers, the seed companies package their maize seed in 2kg packet. A two

kilogram packet of maize seed retails at an average price of US $ 3.6. Working with the above figures projects to seed companies having lost up to US $ 3,011,148 from the field rejections alone. Calculations from the rejections done at the laboratory level, the 1.5M Kg of seeds that were rejected could otherwise have fetched up to US Dollars 2,700 000. In total on average, seed companies have lost more than US Dollars 5,711,148 this amount is excluding losses incurred from other cost of production that were already invested by this seed companies during the process of this seed production to the levels at which rejections were done.

The results above include samples that were from both local and imported consignments sampled during the period. From the above results, 2.3% of total samples that were tested during the period between 2013 and 2015 tested positive for MLND. Each sample represents a seed crop harvested from a field of not more than 2.5Ha. On average, a seed crop would range between 5000kgs to 40,000kg of maize. An average of 1.5million Kilograms of MLND infected maize seed were prevented from reaching the farmers in Kenya during that period. This amount of seeds plus more others rejected during field inspection together would have provided a huge amount of inoculum for spreading MLND. This would have been a big blow to the fight against MLND especially where the seeds would have been purchased and planted in many parts of the country.
Taveta and Bura have had no positive samples properly due to their geographical isolation from maize growing areas in Kenya. On the other hand, the central Rift has had the highest rejections considering that this is the area where the disease was first reported in Kenya. Furthermore, cultural practice for maize farmers in this region could have immensely contributed to this since small scale farmers had maize on their farms throughout the year. The climate in the central and south Rift could also favour the disease since it is almost evergreen throughout the year. Trend analysis of the above results indicates that the disease severity has been on the decline since 2012.

CONCLUSION

Embracing the idea of disease exclusion has been and is still the best ever approach in disease management MLND not being an exception. From the data above, a long stride was made in management of MLND in Kenya through the amendment of seed certification guidelines. Laboratory testing plays an important role in management of disease especially where many seed lots that were approved at field level failed at the laboratory stage. The overall multiplier effect of a single infected plant in a seed crop field is generally large when not controlled. Striving at ensuring high quality of agricultural input, if well implemented can ultimately help in ensuring food security globally. MLND is still a disease in Maize that still requires monitoring in irrigated field where there is no observation of closed seasons for maize.

RECOMMENDATION

Evaluations for new maize varieties for resistance or tolerance to MLND should be augmented in management of MLND. Seed certification measures that have led to the reduction of the disease should be entrenched in the seed laws and implemented fully. Irrigation schemes and other seed growers should be guided to observe closed maize season to reduce disease inoculum. Phytosanitary measures should be observed strictly even for seed material to exclude MLND from countries where it is not known to occur. A full proof of laboratory test for MLND should be demanded at all border points to ensure the disease is managed and spread to disease free countries is controlled. National laboratories should be equipped to produce more efficient and accurate results.

LIST OF ABBREVIATIONS

Form SR9: Seed Regulation 9
ISTA: International Seed Testing Association
KEPHIS: Kenya Plant Health Inspectorate Service
MCMV: Maize chlorotic mottle virus
MLN: Maize Lethal Necrosis
MLND: Maize lethal necrosis disease
PCR: Polymerase Chain Reaction
SCMV: Sugarcane mosaic virus

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7.5 Mango pollinators and their spatial differences across a forest-farm gradient in Kilimambogo, Machakos County, Kenya

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Theme: Crop Improvement, Biotechnology and Climate Change

ABSTRACT

Pollination is critical for mango *(Mangifera indica)* fruit set and formation of quality fruits. As such, it increases tree productivity, enhances and secures farmer incomes. However, considering that pollinators are not managed in Kenya, evidence showing their status is critical to guide in decision making for pollination management. This

study was carried out to determine potential mango pollinators and their spatial differences across a forest-farm gradient in Kilimambogo, Machakos County in Kenya. Three sectors were selected based on their distance from the forest (0.2km, 5km and 10km). Five randomly selected plots separated by a distance of 0.2 km represented each sector. In each plot, 5 trees were randomly selected for observation of flower visitors. A total of 35 species of the flower visitors were observed representing order Coleoptera, Hymenoptera, Lepidoptera, Diptera and Hemiptera. The most abundant mango flower visitors were blow fly (*Chrysomya chloropyga*)(60.8%), honey bee (*Apis mellifera*)(3.7%), flesh fly (*Sarcophaga* sp) (2.5%)and housefly (*Musca domestica*)(1.9%). The findings clearly shows that flies are more important pollinators of mango compared to honeybees, as has been recently reported in Asia and Australia. flower visitor abundance and diversity reduced from farms closer to the forest edge towards the farmland (1409, 1225 and 653 individuals respectively) an d diversity. This can be attributed to the availability of nesting resources and/or mating sites in the natural habitat. These findings provide evidence that forest fragments and patches of natural habitats may act as reservoirs for a diversity of insects that provide crop pollination services to the adjacent farmlands. We recommend holistic pollinator management plan for farmlands in Kenya.
Key words: Pollinator, Mango, spatial distribution, *Chrysomya chloropyga, Apis mellifera, Musca domestica,* forest-farm gradient

INTRODUCTION

Pollination is an ecological process fundamental for the maintenance of the viability and diversity of flowering plants and provides important ecosystems services to humans (Allen-Wardell *et al*., 1998; Daily *et al*., 1997; Kevan, 1999; Klein *et al*., 2007). According to Kevan and Phillips (2001) the importance of pollination in agriculture has been recognised for millennia. It has been reported that pollinator species differ in morphological characteristics and behaviours that determine their ability to pollinate (Horsburgh *et al.* 2011). The most effective pollinator species are those occurring in high abundance, actively moving from flower to flower (has a high visitation rate) and transferring many pollen grains on the stigmas (Rader *et al.* 2009). Mango is one of the most popular fruits within the tropics, and belongs to the family Anacardiaceae and genus *Mangifera* (Abidin, 1990). According to (Bally 2006; Aliakbarpour and Che Salmah 2010), mango flowers are visited by various insects such as wasps, ants, flies, butterflies, beetles, and bees. Mango production in Kenya is usually by smallholder farmers ranging from few trees to different size of orchards. This study therefore, seeks to determine potential mango pollinators and their spatial differences across forest-farm gradient. In Kenya, there is no prior study on Mango-pollinator relationship that has been carried out.

Materials and Methods

The study was carried out in Tala, sub-county located in Machakos County on the eastern slope of Kilimambogo forest. The study area stretches from latitudes 00° 45' south to 10° 31' south and longitudes 360° 45′′ east to 370° 45' east. The research was conducted in two seasons (dry and wet seasons) over a period of six months from August 2015 to February 2016. Months of September and October 2016 comprised the flowering period, November-January fruit development period, and February 2016 the harvesting period. The experiment was set up in a transect through forest farm gradient stretching from the edge of the forest to about 10000m from the forest edge. Three sectors were identified to represent farms near the forest; 200m from forest edge, about 5000m from forest edge and 10000m from forest edge. In each sector five plots were randomly selected, separated by a distance of about 200m and two orchards were identified and supplemented with honey bees. A single farm constituted a plot containing at least 10 mango trees (orchard). To assess pollinator diversity and abundance, 5 plants in each plot were randomly selected. Most of the observations were carried out on a sunny day. Each plant was observed for one hour and the abundance of each visitor species recorded. Observations were done when plants were 50% blooming. Activity of the insect visiting mango flowers was recorded (whether they were collecting nectar or pollen) after which some were captured by sweep net and placed in a kilner jar containing ethyl acetate for identification at the National Museum of Kenya and pinned in the insect boxes.

An exclusion experiment was set up across the three sectors where by 5 trees per farm plot were randomly selected. For each tree, 1 branch with 2 immature inflorescences were randomly selected by taking care that the panicles were of the same height, and approximately same length and exposure to sunlight. Tagged inflorescence were left open for pollination to take effect while tagged inflorescence excluded pollinators (no pollination by external forces was allowed) by using mosquito net with very fine mesh that is impermeable to pollen.

The collected data was entered in excel and imported to Genstat version 17.0. Species diversity index determined using Shannon-Wiener (H) for diversity. For the treatment that is both tagged and tagged the mean was used in all the three sectors and ANOVA was used to determine if it is significant.

RESULTS AND DISCUSSION

A total of 3,284 insect samples, comprising 35 insect species of flower visitors were collected. The insect groups were coleopterans, hymenopterans, lepidopterans, dipterans, and hemipterans. Among the pollinating insect species found in the mango farms, the most abundant flower visiting taxa were *Chrysomya chloropyga* (1996), *Apis mellifera* (120), *Musca lusoria* (61), and *trigona sp* (24) over the two seasons. These findings were in line with those of Bally (2006) and Aliakbarpour and Che Salmah (2010), who noted that mango flowers are pollinated by various insects such as wasps, ants, flies, butterflies and beetles. Flower visitations were same despite the differences in varieties of mangoes that were flowering. This observation is in line with the findings of Anderson, (1982) who noted that majority of the pollinators choose nectar of mango flowers as their food resource. Other taxa occurred in relatively less abundance as shown in Table 1, confirming that insects play a critical role in pollination of mangoes.

Sung *et al*. (2006) reported that honey bees (*Apis spp*.) and flies (*Musca domestica* and *Chrysomya megacephala*) were responsible for successful pollination hence good mango production in Taiwan. Similarly, this study also observed that more than 50% of insects captured were dipterans (Table 1), and seemed to be potential pollinators of mango flowers.

Table 1: Percentage of pollinators (different orders) observed on mango at Kilimambogo

Order	Pollinators	Percentage (%)
Diptera	*Chrysomya chloropyga*	60.8
	Musca lusoria	1.9
Hymenoptera	*Apis mellifera*	3.7
	trigona sp	0.7

Species diversity index shows that diversity decreased with increasing distance into the farmland from the forest edge (Table 1) indicated that sectors 1, 2 and 3 had diversities of 1.4, 1.3 and 1.2 respectively (Table 1. The index values ranges from 0 - 4.6, and for this case the values in the middle indicated that the numbers of individuals are not evenly distributed between all the species thus this measure provides a possibility of comparing species based on locality. According to Carvalheiro *et al*. (2010), flower visitors are negatively affected by distance to natural habitat. The study also observed the highest number of flower visitors at Sector 1 (1409), sector 2 (1225) and sector 3 (656) (Table 2). At sector 2, most of the farmers had strips and patches of land left uncultivated.

Table 2: Diversity and abundance for 3 sectors

Sector	Distance from forest edge	Abundance	Diversity (H)
1	0-200m	1409	1.4
2	5000m	1225	1.3
3	10,000	656	1.2

The effect of flower visitors on mango fruits development

Seven weeks after bagging and tagging (flowers left open for natural pollinator visitations) of branches, the development of fruits indicated that the tagged branches had the highest number of flowers than the bagged branches (Fig. 1). The average number of fruits in the tagged branches was 3.4±1.0, while the bagged was 1.6±0.2. The observed differences were significant (ANOVA, F=2.845, $p \leq 0.05$). From the experiment set up, it was observed that mangoes are dependent on pollinators for fruit development. This observation is in agreement with the findings of studies carried out by various authors (Free and Williams, 1976; Anderson, 1982; Richards, 2001; Carvalheiro *et al.*2010). These studies observed that pollinators are critical for successful fruit set of mango flowers. Contrary to our expectations, some panicles as shown in figure 1 were able to bear fruits which indicated that mangoes were able to set fruits despite exclusion of insect. Similar observation has been reported by Free and Williams (1976), who suggested that at least some pollination is assisted by wind or gravity.

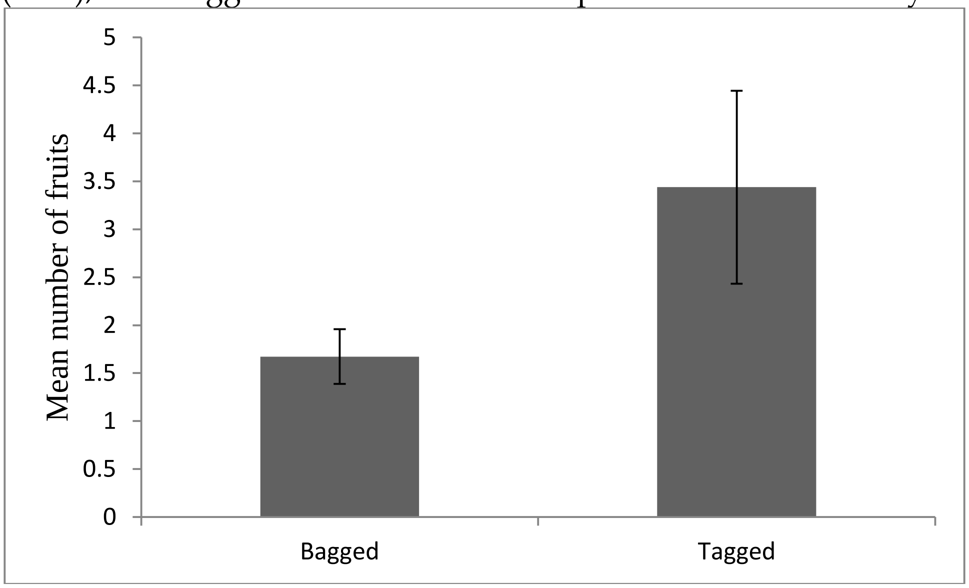

Figure 1: Mean number of fruits observed on bagged and tagged flowers

The importance of natural habitat on the yield of mango

During the experiment both diversity and abundance differed across the sectors depending on the distance from natural forest. The highest abundance of 42.9% was recorded at sector 1, sector 2 (37.3%) and at sector 3 (19.8%). Both abundance and diversity of flower visitors have been noted to influence the efficiency of pollination process (Kremen *et al.*, 2002; Carvalheiro *et*, 2010).

The study observed that plots located at 200m from natural forest had the highest mean number of mango fruits development (7.2±2.5) in tagged flowers (Fig. 3). On the contrary, plots located 5000m and 10000m from natural forests recorded very low mean number of fruits that developed (0.8±0.2 and 1.2 ±0.4) in tagged flowers.

Study on bagged flowers recorded low mean fruit development (1.8±0.5), 200m; 1.1±0.3), 5000m; 2.0±0.6), 10000m that also varied minimally between plots located at 200, 5000 and 10000 metres from the forest (Fig. 2). Even though distance does not affect the yield of the mangos directly, it significantly plays a critical role in determining the number of wild pollinators that reach the farms. Natural habitats provide two valuable benefits to mango plantations; they are a source of pollinators for crop pollination, and also act as refugia for pollinators that can colonize degraded agricultural areas (Ockinger and Smith, 2007).

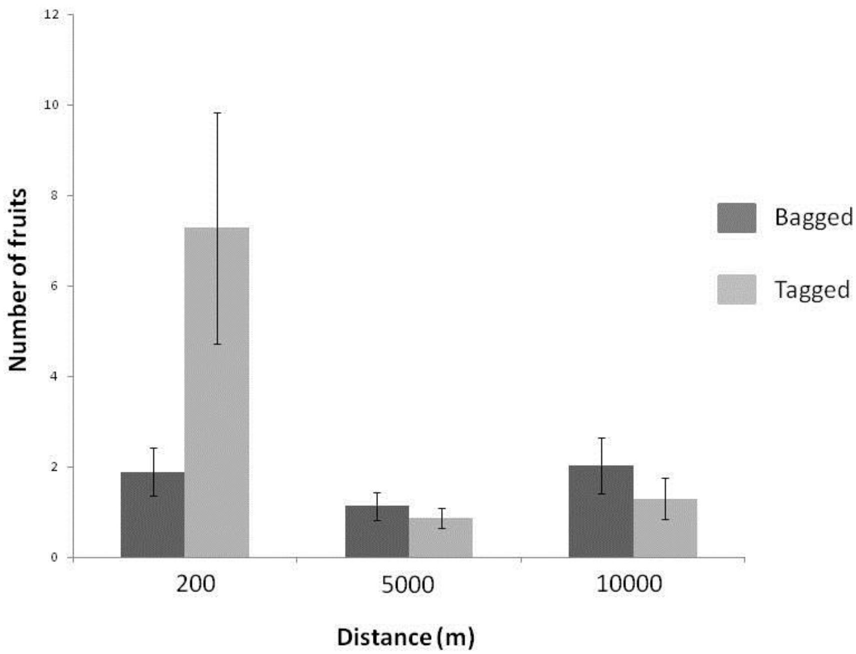

Figure 2: Mean number of fruits developed in both bagged and tagged at 200m, 5000m and 10,000m from natural forest

CONCLUSION

Pollinators play a critical role in formation of fruits in mangoes, and pollinators decline with distance from the natural habitat those farms that are near the natural habitat benefitted from the presence of wild pollinators. Most of the insects belonged to the orders of diptera and hymnoptera. The important pollinators are blowfly, honeybees flesh fly and housefly. For farms that are away from natural habitat conservation of the pollinators within farmland is very critical

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7.6 Low cost insect proof and micro-climate regulating Agronets are effective in managing infestation of American Bollworm (*Helicoverpa armigera* Hubner.) on field tomatoes in Nairobi and Kiambu counties, Kenya

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ABSTRACT

Fruit damage by the American Bollworm (*Helicoverpa armigera* Hbn.) is a major challenge to small holder tomato (*Solanum lycopersicum* L.) farmers in Kenya. Pesticides though highly used have not effectively delivered best control system. The study was conducted on-station at Kenya Agricultural and Livestock Research Organization Kabete and Thika Practical Training Center to assess the effects of Agronets in the reduction of *H. armigera* damage and thus increase yields. Treatments included covering the crop with fine mesh Agronets (0.4 mm) throughout the season, fine mesh Agronets (0.4 mm) opened three times a week from 09:00-15:00h, large mesh Agronets (0.9 mm) covered throughout, large meshed Agronets (0.9 mm) opened three times a week from 09:00-15:00h, and a control (no Agronet). Each treatment was replicated five times in a completely randomized block design. The results show that there were significant treatment effects in the density of *H. armigera* infesting the crop as well as damaged fruits and yield. Non-protected tomatoes recorded significantly higher infestation, damage and lower yields compared with tomatoes protected using Agronets. Yields were however not significantly different even though unprotected tomatoes were fewer. It is concluded that further studies are warranted to provide best innovative way of covering the tomatoes. This is in consideration that there is recorded efficiency in reducing infestation by bollworm and therefore aspects of covering are important to consider and probably include an integrated pest and disease management approach to further reduce fruit loses.

Key words: mesh size, pest, fruit damage, yield, tomatoes

INTRODUCTION

The African bollworm, *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) is one of the worst agricultural pests in Africa. It attacks a variety of food and cash crops and has been recorded as a damaging pest on 180 cultivated and wild plant species in at least 45 families. Just like in most insect pests, control of American bollworm requires careful monitoring and integration of appropriate control measures. Farmer's approach to the management of the American bollworm relies mainly on frequent applications of pesticides with long-term persistence. However, pesticides application by small-scale farmers is generally inefficient due to the protected habitat of the larvae, poor application techniques, quick development of resistance and the fact that some pests such as the American bollworm are nocturnal (Gogo *et al.,* 2014). On the other hand, pesticide applications are also injurious to human health, environmental safety and beneficial insects. National and international concern about this situation, the broad involvement of aid agencies in pest control programs, and recent successes of the concept of integrated pest management (IPM), formed the basis of this study. This study was carried out to determine efficiency of low cover netting on tomato to manage infestation of American bollworm. This netting technology has been tested previously in Benin and found effective on diamondback moth, *Plutella xylostella* (Martin *et al.*, 2013) and in Kenya on tomatoes against *H. Amigera*; Gogo *et al*. (2014) and Juma *et al*. (2015).

MATERIALS AND METHODS

Experimental site and Study design

On-station field studies were conducted at Kenya Agricultural and Livestock Research Organisation (KALRO) National Agricultural Research laboratories (NARL), Nairobi County and at Thika Practical Training Center (PTC), Muranga County in two cropping periods (under irrigation), from May 2009 to September 2009 and July 2009 to October 2009 respectively. Experimental plots 8 m^2 (8 m long x 1 m wide) were used with a spacing of 50 cm. Commercially available tomato var Riogrande® seedlings were sourced from a six week old nursery covered with a fine mesh sized Agronet.

The experiment was laid out in a completely randomized block design layout with five replicates. Five treatments were tested; Non-protected control (no Agronet), Agronet with fine mesh (0.4 mm) used permanently, Agronet with large mesh (0.9 mm) used permanently, agronet with fine mesh (0.4 mm) opened 3 times a week (Mondays, Wednesdays and Fridays) from 9 am to 3 pm and Agronet with large mesh (0.9 mm) opened 3 times a week (Mondays, Wednesdays and Fridays) from 9 am to 3 pm.

Data collection

Pest abundance: American Bollworm larvae incidence and count was recorded based on a stratified random sampling procedure whereby each plot was divided into three parts (strata) of five plants each and any plant from within each stratum sampled on a weekly basis to check larvae incidence as well as count their population up to harvest.

Quality and yield: Harvesting was carried out from twelve weeks after transplanting for seven consecutive weeks. The total number of fruiting plants in each plot was counted after which the harvesting process commenced. All fruits with a breaking colour were hand-picked in respective plots and bagged in well labeled bags and taken to the laboratory for weighing using an electronic balance. In the laboratory, the fruits were sorted and graded according to pest infestation as well as market grade. Each fruit category was then weighed and recorded based on the insect damage inflicted on them. Evaluation of insect pest damage on the fruits involved counting the number of fruits observed with punctures or blemishes on the skin as well as those which were unaffected thus categorisation into marketable and unmarketable grades for the respective treatment plots.

Data analysis

GENSTAT discovery edition IV software was used to carry out the statistical analysis. Data on the pests' abundance and crop yield was subjected to Analysis of Variance (ANOVA) for comparisons at 5% confidence limit. Data on pest abundance however revealed strong evidence against normality. This data was thus square-root transformed $(x + 0.5)^{0.5}$ before ANOVA was carried out. Means that showed significant differences were separated using Student-Newman-Keuls (SNK) multiple range test method.

RESULTS

Abundance of American bollworm infesting tomatoes grown under Agronets in Kenya

There were no significant differences ($F_{4,595}$=1.26; P=0.29) in the mean number of *H. armigera* recorded on tomato plants across treatments in the first cropping season (Table 1) but significance ($F_{4,595}$=2.47; P=0.05) was recorded in the second cropping season (Table 1). The highest mean number was recorded on treatments with fine mesh Agronet closed permanently (0.56 ± 0.31). This was followed by the treatments with fine mesh Agronet opened three times a week (0.12 ± 0.07), the large mesh Agronet covered permanently (0.04 ± 0.02) and the large mesh Agronet opened three times a week (0.04 ± 0.02) which did not differ significantly. The control treatment had the lowest mean number recorded, (0.012 ± 0.01).

Effect of Agronets on the quality and yields of tomatoes in Kenya

There were no significant differences ($F_{4,595}$=0.22; P=0.93) ($F_{4,595}$=1.24; P=0.30) in the mean fresh weight of non-marketable tomatoes harvested in the first cropping season (Table 2). However, in the second cropping season, significant differences were observed. The highest mean number was recorded on the control treatment (4.95 ± 1.18). This was followed by the fine mesh Agronet treatment covered permanently (2.44 ± 1.44) which did not differ significantly with the control. This was followed by the large mesh Agronet opened three times a week (1.62 ± 0.60), then the large mesh Agronet covered permanently (1.35 ± 0.55) and then the fine mesh Agronet opened three times a week (1.30 ± 0.55), which had no significant differences between them and the fine mesh

Agronet treatment covered permanently (Table 2). There were no significant differences ($F_{4,595}$=0.16; P=0.96) ($F_{4,595}$=1.40; P=0.24) observed on the mean number of fruits harvested in the first and second cropping seasons respectively. No significant differences ($F_{4,595}$=0.41; P=0.81) ($F_{4,595}$=1.11; P=0.35) were also observed in the mean fresh weight of fruits harvested in the first and second cropping seasons respectively.

Table 1. The mean numbers ± S.E of larval *H. armigera* and the mean fresh fruit weight ± S.E of non-marketable fruits recorded on tomato plants in the first and second cropping seasons

	Mean number of *H. armigera* larvae / plant		Mean fresh fruit weight of non-marketable tomatoes /plant (g)	
Treatments	1st Season	2nd Season	1st Season	2nd Season
FMA (P)	0.02 ± 0.01	0.56 ± 0.31c	58.26 ± 11.58	2.44 ± 1.44ab
FMA (3T)	0.02 ± 0.01	0.12 ± 0.07b	52.14 ±11.95	1.30 ± 1.30a
LMA (P)	0.03 ± 0.01	0.04 ± 0.02b	27.29 ± 6.81	1.35 ± 0.55a
LMA (3T)	0.04 ± 0.01	0.04 ± 0.02b	57.62 ± 19.64	1.62 ± 0.60a
Control (No Agronet)	0.05 ± 0.02	0.012 ± 0.01a	42.44 ± 4.53	4.95 ± 1.18b
$F_{4,595}$; $F_{4,170}$	1.26	2.47	1.15	2.65
P-Value	0.29	0.05	0.33	0.04

Key: FMA (P) = Fine mesh Agronet closed permanently, FMA (3T) =Fine mesh Agronet opened three times a week, LMA (P) =Large mesh Agronet closed permanently LMA (3T) =Large mesh Agronet opened three times a week.
Means within a column followed by the same letter are not significantly different at P= 0.05. Test statistic was ANOVA and means separated using SNK.

DISCUSSION

The *H. armigera* infestation was low across the seasons probably providing a reasoning why a no significant difference was reported. In the second cropping season, results on the abundance of *H. armigera* infesting tomatoes in Kabete showed that there were significant differences in the mean number of *H. armigera* recorded on tomato plants. Highest infestation was observed on the treatment with the fine mesh Agronet covered permanently followed by the rest of the treatments with no significant differences between them and the lowest on the control (no Agronet) treatment. *H. armigera* infestation observed inside the Agronet treatments may have been initiated from small caterpillars crawling across the Agronets as well as those hatching from pupae deposited on the ground before laying out of the treatments. This pest is known to be occasional hence the infestation levels follow expected population dynamics of this pest. Majumdar (2010) also reported that occasional pest outbreaks observed inside net houses may be as a result of insects emerging from the soil or small caterpillars crawling across the net. *H. armigera* infestations are also thought to have been higher under Agronets treatments than in the control (no Agronet) treatment probably due to reduced action of natural enemies excluded by the covered Agronet plots. This finding on natural enemy exclusion by Agronets agrees with results from Martin *et al*. (2013) who reported that Agronets should be removed sometimes during the day to allow natural enemy activity as they appeared to represent a serious barrier for them. The fine mesh Agronet treatment in this study is also thought to have the highest mean number of *H. armigera* probably due to restricted entry of natural enemies onto the crop and exit of the pest from the crop as a result of the mesh size and covering of the crop throughout when compared to the rest of the treatments that were either opened three times a week or not covered at all (control). According to Majumdar (2010), cover pore diameter affects entry and exit of insects into the crops, thus justifying findings of this study. Berlinger *et al.* (2002), Martin *et al.* (2013) and Gogo *et al*. (2014) in their studies also showed that opening the nets during the day improved the protection of plants against pests probably because of the regulatory effect of beneficial insects. One of the main objectives of the use of Agronets was to protect the tomato plants from insect pest infestation and consequently damage to the fruits. Data collected on the quality and yield of harvested tomato fruits showed no statistically significant differences between treatments. The results of this study however clearly showed that use of temporary net covers for the protection of tomato crop can be an effective tool to protect plants against lepidopterans, corroborating earlier findings by Martin *et al*. (2013) and Licciardi *et al*. (2008) who worked on cabbages in Africa and Benin respectively. Generally the high marketable yields recorded in the study were attributed to use of Agronet covers for the protection of insect pests. At harvest, damage by *H. armigera* was the single most important source of yield loss resulting from insect damage, accounting for over 50% of the unmarketable yield. This finding is in line with those of Maerere *et al*. (2010), Gogo *et al.* (2014) and Juma (2015) who stated that *H. armigera* accounted for more than 50 % of unmarketable yield in open field check plots that had no treatments applied. Overall, the effects of Agronets on pest control and yield were positive. *H. armigera* is a significant threat to tomato production in Central Kenya. Effective control of this pest is inevitable for attaining reasonable yield levels. These findings on yield agree with results on field trials carried out by Gogo *et al.* (2014) and Juma (2015) who compared pest infestation on tomatoes grown in the open to those grown under Agronets. Gogo *et al.* (2014) concluded that Agronets are a viable strategy for improving tomato yields through reduction of the American Bolloworm population on tomatoes and can be incorporated as a component of integrated pest management strategy. Juma (2015) also concluded that Alpha-cypermethrin treated Agronets with a cover mesh diameter of 0.9 mm was effective in protecting tomato plants and tomato seedlings against major pests especially *A. gossypii*, *B. tabac*i, *L. trifolii*, *Planococcus* spp. and *H. armigera*.

CONCLUSION AND RECOMMENDATION

Despite use of Agronets, pest entry into protected plots was noted thus called for additional pest management input to reduce pest pressure thus complementary pest control measures may be required alongside Agronet use. Large mesh Agronet covers opened three times a week gave better control of *H. armigera* when compared to the fine mesh size nets as well as those covered throughout since natural enemies were allowed to locate their hosts hence control pest populations considerably. Higher yields were generally recorded on tomatoes grown under Agronets when compared with control plots (no Agronets).

Agronet covers should be used in an IPM strategy that would be effective in controlling key insect pests of tomatoes as well as increasing tomato yields. When used alone, pest pressure may drastically affect the crop and consequently result to a decline in yield.

To be effective, Agronets must necessarily be installed prior to the pests' appearance and all openings must be totally covered by the Agronets, including entrances. Complementary pest control measures are also required to reduce pest pressure. Augmentative release of natural enemies should be considered for the control of tomato pests when Agronets are used. Agronets should be removed sometimes during the day to allow natural enemy activity. The 0.9 mm mesh size net used on a temporal basis is recommended for the control of key tomato insect pests when compared to the other treatments tested in this study.

ACKNOWLEDGMENTS

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7.7 Appropriate pollinator management scheme for kenyan farmlands

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ABSTRACT

A one year (2014-2015) study was carried out in three regions representing low, medium and high agriculture intensification to determine presence and distribution of pollinators and their nests in farmlands bordering nearby natural habitats of Mt Kilimambogo forest, Kakamega forest and Mt Kenya forest, respectively. This is in response to scientific evidence in Kenya showing increasing pollination deficit of various pollinator-dependent crops, which is responsible for declining yields both in quantity and quality. The results of this study show that pollinator nests are more concentrated in farms farther from the forest as the forest provided nests for bees found around the forest. In addition, the pollinator density reduces with increasing distance from the forest. In all the regions, hedgerows were a permanent feature, under different level of heterogeneity. It was found that some plants flowered all year round, attracting and providing various pollinators food resources. Some of these plants had pithy stems capable of providing bee nests. This study provides an opportunity to implement catchment approach pollinator management scheme that include various aspects of

understanding, utilizing and protecting pollinators at farm level. The paper provides detailed analysis of the scheme and proposes best implementation approach to ensure farmers benefit from this essential ecosystem service.

Keywords: agro-ecology, bee forage, bee nests, ecosystem service

INTRODUCTION

Pollination is an essential ecosystem service for increased crop production. About 35% of global crop production is attributed to the work of pollinators (Klein *et al.,* 2007). Animal mediated pollination is carried out by insects, birds, butterflies, ants, among others; of which 90% is by bees (Michener, 2000). Out of the 2000 species of bees recorded (Kremen *et al.,* 2007), about 3,000 species have been found in sub-saharan Africa (Gikungu, 2006). In Kenya, several studies have indicated that bees are the most important pollinators of most crops (Gikungu, 2006; Kasina *et al.,* 2009a; Oronje *et al.,* 2011). There have been concerns of pollinator decline in various parts of the world especially in Europe and North America (Kearns *et al.,* 1998). In Kenya, though not yet documented, some research done at Kakamega has shown that the number of bees have decreased (Kasina *et al.,* 2009a). Anthropogenic factors such as clearance of land for agriculture resulting in habitats loss, pesticides use and little knowledge on bees resulting to their loss (Tuell and Isaacs, 2010) are the main reason for this decline. Loss of biodiversity has led to a reduction in pollination services, which are needed to ensure sustainable food production (Morandin and Kremen, 2013). One of the ways of conserving the pollinators is by increasing the diversity of floral plants in farmlands so that bees have sufficient foraging and hiding sites (Kirk and Isaacs, 2012; Mwangi *et al.,* 2012). Hedgerows have been cited as important in providing both forage and nesting for bees (Tuell and Isaacs, 2010; Gonigle *et al.,* 2016). In Kenya no study has yet be carried out on the effectiveness of hedgerows in providing nesting sites for bees. This implies that bee presence in the farmlands is not assured and ultimately yields are reduced. Therefore this study sought to determine which bees visited hedgerows for forage, nesting and the best combinations of plants on the hedgerow that provided floral resources for bees throughout the year.

2 Materials and Methods

The study was carried out in three sites; Mt Kenya, Kilimambogo and Kakamega forest along a transect from the forest towards the farmlands. In each site four sectors were chosen separated by a 5km distance for data collection purposes. Data on number of nests and plants visited was documented on monthly basis for a year. Data analysis was done using GENSTAT statistical software. Skewed data was subjected through square root transformation to normalize it. Analysis of variance (ANOVA) was used to compare means across the sectors and significance was sought at 95% level of confidence limit. Significant means were separated using the Fishers protected LSD (least significant difference).

RESULTS AND DISCUSSIONS

Kakamega site recorded more nests (41.5%) compared with Mt. Kenya and Kilimambogo sites (33.3% and 25.1%) respectively. A significant (P=0.014) difference in the number of nests per site was recorded (Table 1). Nearer the forest, fewer bee nests were found on the hedgerows compared to the sectors far away indicating that the forest was providing nesting sites for bees found nearby (Fig 1). This corroborates with earlier studies in Kakamega (Hagen 2008; Kasina *et al.,* 2009b) where more bees were found inside forest as there was abundance of forage and nesting sites for them compared to the farmland. Similar studies indicated that, it was impossible for bees to live without forests as this is their main source of nesting and forage (Gikungu, 2006).

Table 1: Number of bee nests recoded at various sites in Kenya, October 2014

Sites	Number of nests (Percentage)	Mean
Kilimambogo forest	204 (25.1)	50.75a
Mt. Kenya forest	272 (33.3)	68.00a
Kakamega forest	339 (41.5)	84.75b
P value	0.014	

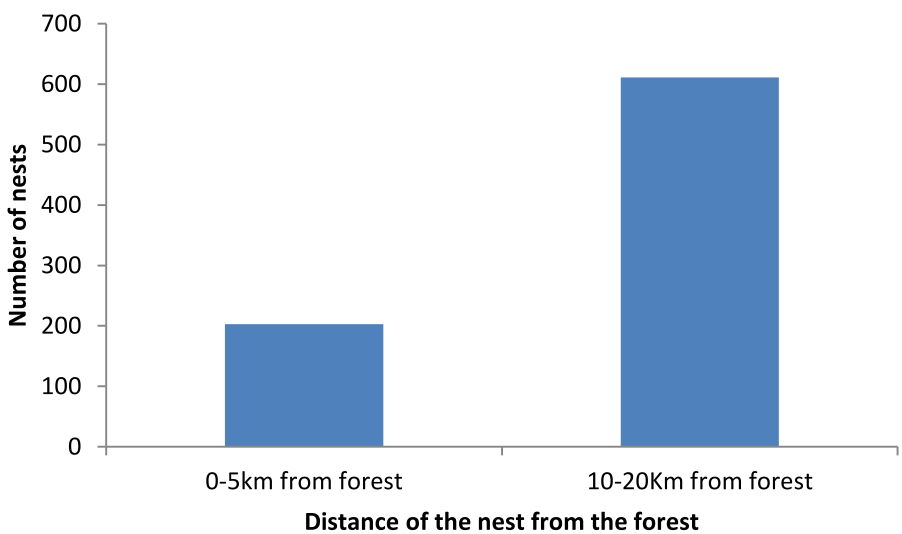

Fig 1: Number of nest found at various distances from forest

About 80% of the nests found in Mt. Kenya, Kilimambogo and Kakamega sites were made of wood and the rest were found on the ground. This conforms to earlier studies by Michener (2000) who noted that species of Apidae, Megachilidae and Colettidae use abandoned nests located in wood cavities. Presence of few ground nesters is an indication of absence of a certain preference for nesting by bees. For example, excessive mulching with wood chips has been found to affect ground-nesting bees, which need bare soil or a thin layer of natural leaf litter (Frankie *et al.*, 2009). Hedgerows harboured 80% of all the nests recorded while the rest were found on the house rafters and within the crop. At the hedgerow, only trees provided sites for large nests. However, most of the trees are pruned and any dead twig used for fuel wood (Kasina *et al.*, 2009b) thus denying these large bees areas to nest on. Thus nests were found on short dry twigs that cannot be harvested for fuel wood due to size limitation. The twigs had pithy stems which were easily tunneled by smaller bees for nesting purposes. Such twigs are quite few, confirming the lower number of large nests on the hedgerows. Practices such as the removal of dry wood around farms are known to destroy nesting sites for solitary bees (Kremen *et al.*, 2007).

Among the observed pollinator floral host plants, only 10 of them were recorded flowering every month of the year (Table 2). Plants in the family Asteraceae were the most common of the plants listed followed by Lamiaceae (Table 2). This confirms earlier studies in Kenya by Gikungu (2006) and Karanja *et al.*, (2010) who reported plants in the family Asteraceae as important bee plants that provide resources for bees throughout the year.

Table 2: Some of the host plants that flowered most frequently in all sectors, September 2013 to August 2014

	Scientific name	Common name
1	*Achyranthes aspera*	Devil's horsewhip
2	*Aspilia mosambicensis*	Aspilia
3	*Bidens pilosa*	Black jack
4	*Commelina diffusa*	Climbing day flower
5	*Lantana trifolia*	Threeleaf verbena
6	*Ocimum suave*	Mtule basil
7	*Plectranthus barbatus*	Indian coleus
8	*Sesbania sesban*	Egyptian pea
9	*Solanum incanum*	Sodom apple
10	*Tagetes minuta*	Mexican marigold

RECOMMENDATIONS

Considering the dependence of farmers on hedgerows to provide fuel wood integrated bee forage and nest management need to be devised, which include capacity building of farmers to enhance their skills on how to conserve and utilize bees for crop production. For example, farmers would keenly include artificial nests based on bee-preferred wood material in the hedgerows and strategic places in the farms.

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7.8 Avocado *(Persea americana)* yield as influenced by pollinators in Kandara, Murang'a County, Kenya

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ABSTRACT

Avocado (*Persea americana* Mill) is an important crop that provides source of income and nutrition for many Kenyans. However, its production is affected by many factors. Pollination has not been considered in the past as a key factor of production. This study was carried out to determine the contribution of pollination to the productivity of this crop in terms of fruit set and fruit yield. It was carried out in farmer fields at Kandara, Murang'a County. The treatments included unlimited access of flowers by pollinators, and preventing access by pollinators. A total of 44 trees were randomly selected in 4 farms in season 1 and repeated in preceding seasons. A minimum distance of about 10 m and 200 m was maintained from tree to tree and farm to farm, respectively. On each tree, two randomly selected terminal branches with inflorescences of the same age and size were identified, one bagged to deny pollinators visits and another left open for unlimited access by pollinators. Preliminary results show highly significant difference (P= 0.002) in fruit yield across the treatments, translating to 70% pollination deficit, which confirms the world recorded pollination deficit of avocado. A 305% increase in fruit set was recorded when flowers were exposed to pollinators. This translated to a

333% increase in fruit yield, considering fruit abortion during the growth period. The study confirms that pollination is a major factor of avocado production. The findings affirm the importance of pollination management in avocado and calls for urgent utilization of pollinators for increased productivity and quality of fruits.
Key words: bees, pollination, avocado pollinators

INTRODUCTION

Avocado (*Persea americana* Mill) is an important crop that provides source of income and nutrition for many Kenyans. However, its production is affected by pollination provision (Perez-Balam *et al.,* 2012), which is a precursor to fertilization of ovules, leading to fruit set. In other parts of the world, avocado is commercially provided with honeybees (*Apis mellifera*) for pollination provision (Ish-Am, 2005). In its nature, the crop is also known to be visited by stingless bees, wasps and flies (Gazit and Degani, 2002; Can-Alonzo *et al.,* 2005; Afik *et al.,* 2006). Lack of sufficient pollinators has been reported to results in no or only a few fruits in Israel, California and South Africa (Ish-Am, 2005). Ish-Am (Ibid.) thus noted that pollination is a limiting factor for avocado productivity. A recent economic analysis in Kenya by Kasina and Gemmill-Herren (2014) and globally by FAO (2009) showed that pollination is important for fruits and result to about 25% yield loss if not provided. Avocado yield-dependence on pollen vectors is much higher than this. Where farmers do not manage pollination, yield losses may be immense. This study was carried out therefore, to determine the contribution of pollination to the yields of avocado in terms of fruit set and fruit yield.

MATERIALS AND METHODS

This study was carried out in farmer fields at Kandara, Murang'a County, which leads in terms of small-scale avocado growing for export market in Kenya. Treatments included unlimited access of flowers by pollinators, and preventing access of flowers by pollinators. A total of 44 trees were randomly selected in 4 farms in season 1 and repeated in preceding seasons. A minimum distance of about 10 m and 200 m was maintained from tree to tree and farm to farm, respectively. On each tree, two randomly selected terminal branches with inflorescences of the same age and size were identified, one bagged to deny pollinators visits and another left open for unlimited access by pollinators to represent 2 treatments replicated 44 times. Fruits from the 2 different treatments were counted for fruit set differences and later harvested at the end of the season to calculate avocado pollination deficit.

RESULTS AND DISCUSSION

A 305% increase in fruit set was recorded when flowers were exposed to pollinators (Figure 1). The difference was statistically significant (p=0.002) confirming that pollen vectoring in avocado is crucial for fruit set as reported elsewhere (e.g. Ish-Am, 2005).

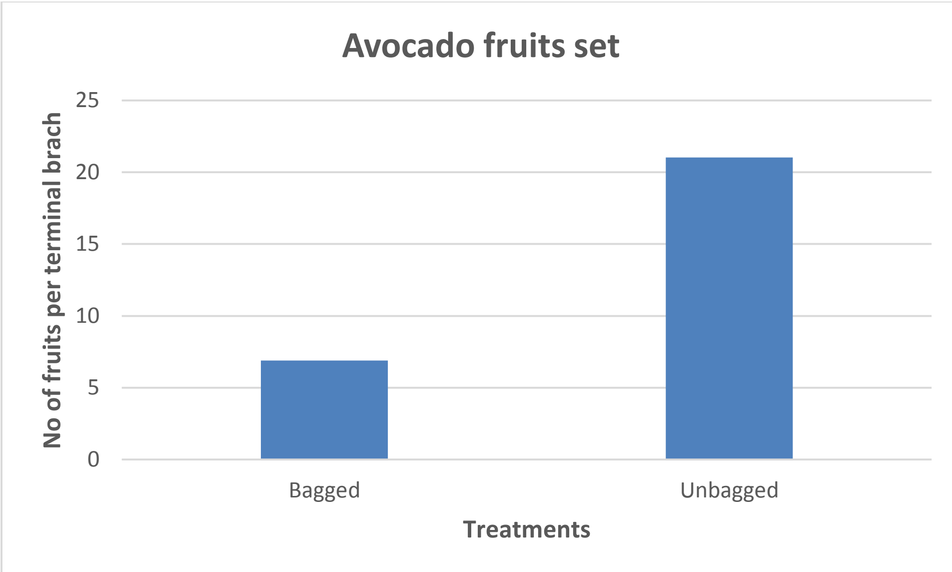

Figure 1: Mean avocado fruits set per tree terminal branch at the start of fruiting

A more than 3-fold increase in fruit yield was recorded when the crop was provided with pollination compared without pollination provision (Figure 2). The difference in yields translates to a 70% pollination deficit, which confirms the world recorded pollination deficit of avocado. This shows that insufficient pollination could be one of the major limiting factors in avocado production in Kenya considering that farmers are not known to manage pollination (Kasina *et al.*, 2009).

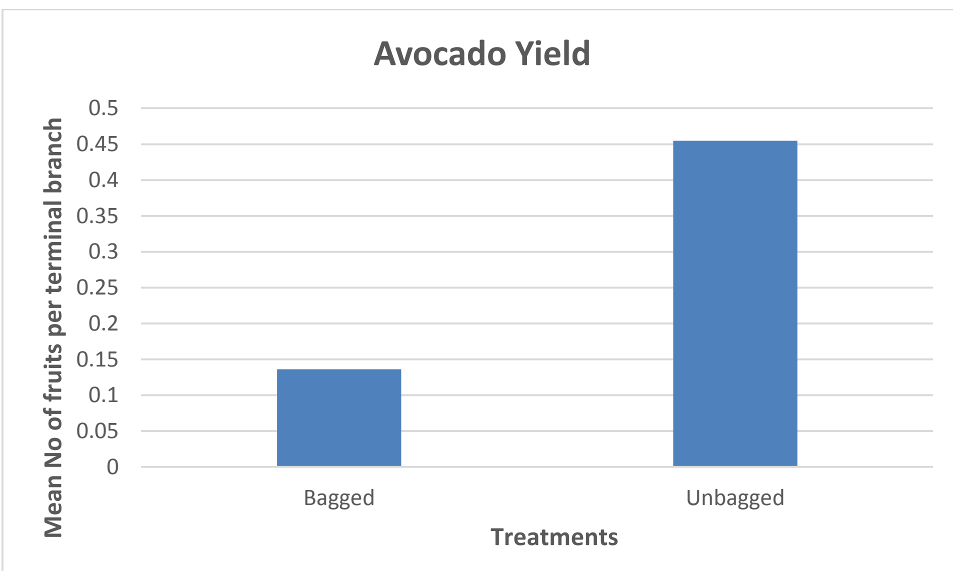

Figure 2: Mean avocado fruits yield per tree terminal branch subjected to different treatments

The study confirms that pollination is a major factor of avocado production. The findings affirm the importance of pollination management in avocado and calls for urgent utilization of pollinators for increased productivity and quality of these fruits.

Indeed, pollination management is a production factor and its lack of management would lead to poor seed set, fruit set and fruit quality (Sabbahi *et al*., 2006).

CONCLUSION

This study found that avocado trees exposed to unlimited access by pollinators resulted to 305% increased fruit set and 333% yield increase compared to those denied pollinator visits. The management and protection of pollinators are therefore of vital importance in avocado production.

ACKNOWLEDGEMENT

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8.Parallel Session 7: Technology diffusion impact and sustainable Agribusiness value chains

8.1 Effect of phosphorous on yield and growth of soybean (*Glycine max L*) varieties in central highlands of Kenya

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ABSTRACT
Soybean (*Glycine max (L.) Merrill*) is one of the most important legume crops being introduced in the smallholder farming systems of the Central Highlands of Kenya to improve income and household nutrition of farmers. However, low phosphorus fixation is one of the major causes of low soybean yields. Central Highlands of Kenya has *humic Nitisols* with high acidity and high inherent Phosphorous fixing. Information on how P affects soybeans in this region is scarce yet critical. The objective of the trial was to evaluate effects of Phosphorous (P) on growth of two soybean varieties (Gazelle and SB 19) and yield. The source of P was Triple Super Phosphate (TSP) which provided 40 kg P ha^{-1} which is the recommended rate. The trial was carried out at Muthambi, Sub County Tharaka Nithi County for two cropping seasons; Short Rains 2015(SR 2015) and Long Rains 2016 (LR 2016). The experimental design was a randomized complete block design (RCBD) with four treatments replicated eight times. The treatments were; Gazelle with 40 kg P ha^{-1},Gazelle with 0 kg P ha^{-1}, SB 19 with 40 kg P ha^{-1}and SB 19 with 0 kg P ha^{-1} .Data was subjected to analysis of variance (ANOVA) in SAS 9.2 and means separated using Least Significant Difference (LSD) (p=0.05). Results showed that there was significant ($P< 0.0001$) difference in plant height and number of pods between the two varieties during SR 2015 season. Result also showed that use of P at 40 Kg/Ha led to increase of Gazelle yields by 34% and that of SB 19 by 7% compared to the control during SR 2015. The study recommends use of Triple super phosphate in central highlands of Kenya in soybean production
Key words: Soybean Gazelle, SB 19, Phosphorous

INTRODUCTION

Soybean [*Glycine max (L.) Merrill*] is the world's leading source of protein and oil. It has the highest protein content of all food crops and is second to groundnut in terms of oil content among grain leguminous crop (Ikeogu and Nwofia, 2013). It also contributes to the improvement of soil fertility through biological nitrogen fixation (Sanginga et al., 2002). The spread of soybean crop from its native land of origin has been mainly due to its adaptability and predominant use as a food crop for human nutrition, source of protein for animals, medicinal plant and lately as an industrial crop (Ikeogu and Nwofia, 2013). Nevertheless, the crop is relative new under traditional cropping systems of Sub-Saharan Africa (Sanginga et al., 2002). In the central Highlands of Kenya, soybean production is increasingly being practiced by smallholder farmers, but the yields are still lower than the reported yields for the Sub-Saharan Africa region. Some of the highlighted constraints in the current attempts for the successful incorporation of soybean crop in to the cropping system of these zones are soil related constraints such as low pH, nutrient deficiencies (phosphorus, nitrogen), and toxic levels of some metals like aluminium and iron (Rubaihayo et al., 2000), and agronomy related constraints such as lack of improved varieties (Ikeogu and Nwofia, 2013).

Soybean, like all other nitrogen fixing leguminous crops, requires P for its proper growth and N fixation. Soybean's effective contribution to soil fertility improvement can be inhibited due to P deficiency (Giller and Cadish 1995). Legumes are especially sensible to low P availability because the biological nitrogen fixation requires high levels of P. The P deficiency can limit the nodules formation while the P fertilization can overcome the deficiency (Carsky et al., 2001). Soils that fix P can severely affect the yields of crops. Phosphorous fixation in the soils increases with the time of contact between soluble phosphates and soil particles. Most of legume crops develop poorly under low soil fertility conditions; especially where the acid conditions of the soils makes free oxides of iron (Fe) and aluminum (Al) to react with soil P forming insoluble compounds, thus not allowing its availability in the soil (Bationo et al., 2011).

Recent studies conducted revealed positive response and lack of response of soybean varieties to moderate P application of 30 kg P_2O_5 ha^{-1} and inoculation with rhizobia was also noted (N2 Africa, 2011). Compared to the control treatment (0kg ha^{-1} P and without application of inoculants), the grain yield in soils with moderate fertility increased from 0.8 t ha^{-1} to 1.5 t ha^{-1} with inoculants application and then to 2 t ha^{-1} when inoculants and P where applied. However, there was no clear response of P and inoculants application in acidic soils similar to the Central Highlands of Kenya. In this region, apart from the soils being acidic, information about the response of soybean crop to phosphorus fertilizers is lacking. Thereby, this study intended to evaluate the response of soybean crop in terms of yield and growth to phosphorus fertilizer.

MATERIAL AND METHODS

Site Description

The experiment was set at Muthambi Sub County; Tharaka Nithi County. It was carried out among eight members of Thagania group during short rain (SR) 2015 season and

Long Rain (LR) 2016 season. According to Jaetzold et al. (2006), The area is in upper midlands 2 and 3 (UM2–UM3) with an altitude of approximately 1,500 m above sea level, annual mean temperature of about 20^0C and annual rainfall varying from 1,200 to 1,400 mm. The rainfall is bimodal, falling in two seasons, the long rains (LR) lasting from March through June and short rains (SR) from October through December. The soils are Humic Nitisols (Jaetzold et al. 2006), which are deep, well weathered with moderate to high inherent fertility.

Experimental design

The experiments were set up in eight farmers' fields. The experimental design was a randomized complete block design (RCBD) with four treatments replicated eight times. The trials were implemented for two cropping seasons; short rains 2015 and long rains 2016. The plots measured 4.0 M by 4.5 M and test crop was Soybean, Gazelle and SB 19 varieties. The treatments were: Gazelle with 40 kg P ha^{-1}, Gazelle with0 kg P $ha^{-1,}$ SB 19 with 40 kg P ha^{-1}, SB 19 with0 kg P ha^{-1}.

Field Management

Land was ploughed manually using a hand hoe. Triple super phosphate (TSP) was the source of P and was applied per furrow and well mixed with the soil during planting. Soybean was sown on 14th and 15thOctober, 2015 by planting 3 seeds per hole. The spacing was at 50 cm × 10 cm inter- and intra-row, respectively. Two weeks after emergence, the seedlings were thinned to 2 plants per hill. First and second weeding and spraying was done during the growing season.

Data Collection

At physiological maturity stage, soybeans were harvested from a net plot of 10.5 m^2. Plants were uprooted and the roots cut using a panga and fallen leaves were collected and weighed together in the field. Subsequently, the pods were threshed and fresh weight of the grain was determined. Thereafter, the grain samples were sun dried and yields were determined and adjusted to 12.5 % moisture content.

DATA ANALYSIS

Data generated were subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS) version 9.2. Least Significance Difference (LSD) at 95% of significance level was used to separate means.

RESULTS

Table 1: The farmer variety assessment tool of SB 19 and Gazelle during SR 2015

	Variety-*(Rate from 1=least preferred, to 10 most preferred)*	
	SB 19	GAZELLE
Number of pods	9	7
Size of pods	8	8
Number of seeds per pod	7	7
Filling of pods	8	7
Early maturity	10	8
Grain yield	8	6
Vigor of plant	7	9
Height of plant	9	7

From the table above farmers rated SB 19 variety better than Gazelle in terms of Number of pods per plant. They rate gazelle and SB 19 equally in terms of the size of the pods. In terms of the number of seeds per pod they rate both varieties equally. They rate SB 19 as better than gazelle in terms of filling of the grains. SB 19 matured earlier than Gazelle. Gazelle had more vigor than SB 19. SB 19 was taller than Gazelle.

Table 2: plant Height, No of pods, yields, Stover yield and weight of 100 seeds during SR 2015

Variety	Weight of 100 seeds(g)	No of pods	Plant height(cm)	Yields(T/Ha)	Stover yield(T/Ha)
Gazelle	19.21[a]	19[b]	43.1[b]	1.67[a]	2.16[a]
SB 19	13.40[b]	34[a]	61.3[a]	1.61[a]	1.75[a]
p-value	<0.0001	<0.0001	<0.0001	0.8559	0.0618
$LSD_{(0.05)}$	1.29	5.53	5.57	0.65	0.43

Numbers followed by the same letter are not significantly different

From the table above there was a significant difference in weight of 100 seeds between the two varieties. There was a significant difference in number of pods and plant height of the two varieties.

Table 3: plant Height, No of pods, yields, and weight of 100 seeds during SR 2015 data

Treatment	Plant height(cm)	Number of pods	Weight 100 seeds(gms)	Yields t Ha-1
Gazelle with 40 kg P ha^{-1}	45.7	21	19.79	2
Gazelle with 0 kg P ha^{-1}	40.49	17	18.64	1.33
SB 19 with 40 kg P ha^{-1}	62.33	34	13.65	1.67
SB 19 with 0 kg P ha^{-1}	60.2	34	13.15	1.55

From the table above SB 19 with 40 kg P ha^{-1} had the highest height with 60.2 cm. Gazelle with 40 kg P ha^{-1} had the highest weight of 100 seeds. Gazelle with 40 kg P ha^{-1} had the highest yield.

Table 4: No of nodules, no of pods, plant height and Yield during LR 2016

Variety	No of Nodules	No of pods	Plant height	Yields(T/Ha)
Gazelle	5.5^{a}	19^{a}	39.55^{b}	0.804^{a}
SB 19	6.1^{a}	18^{a}	46.34^{a}	0.6265^{a}
p- value	0.7934	0.6588	0.0129	0.2155
$LSD_{(0.05)}$	3.843	4.0996	5.2647	0.2855

Numbers followed by the same letter are not significantly different

There was significant difference in plant height of the two varieties with SB 19 being taller than Gazelle.

Table 5: No of nodules, no of pods, plant height and Yield during LR 2016

Treatment	Plant height(cm)	Number of pods	Nodules	Yields t Ha-1
Gazelle with 40 kg P ha^{-1}	39.59	19.7	5.4	0.8563
Gazelle with 0 kg P ha^{-1}	39.51	18.4	5.6	0.7518
SB 19 with 40 kg P ha^{-1}	47.7	20.1	7.9	0.736
SB 19 with 0 kg P ha^{-1}	44.98	16.2	4.1	0.5171

SB 19 with 40 kg P ha^{-1} had the highest plant height and number of pods. Gazelle with 40 kg P ha^{-1} had the highest yield.

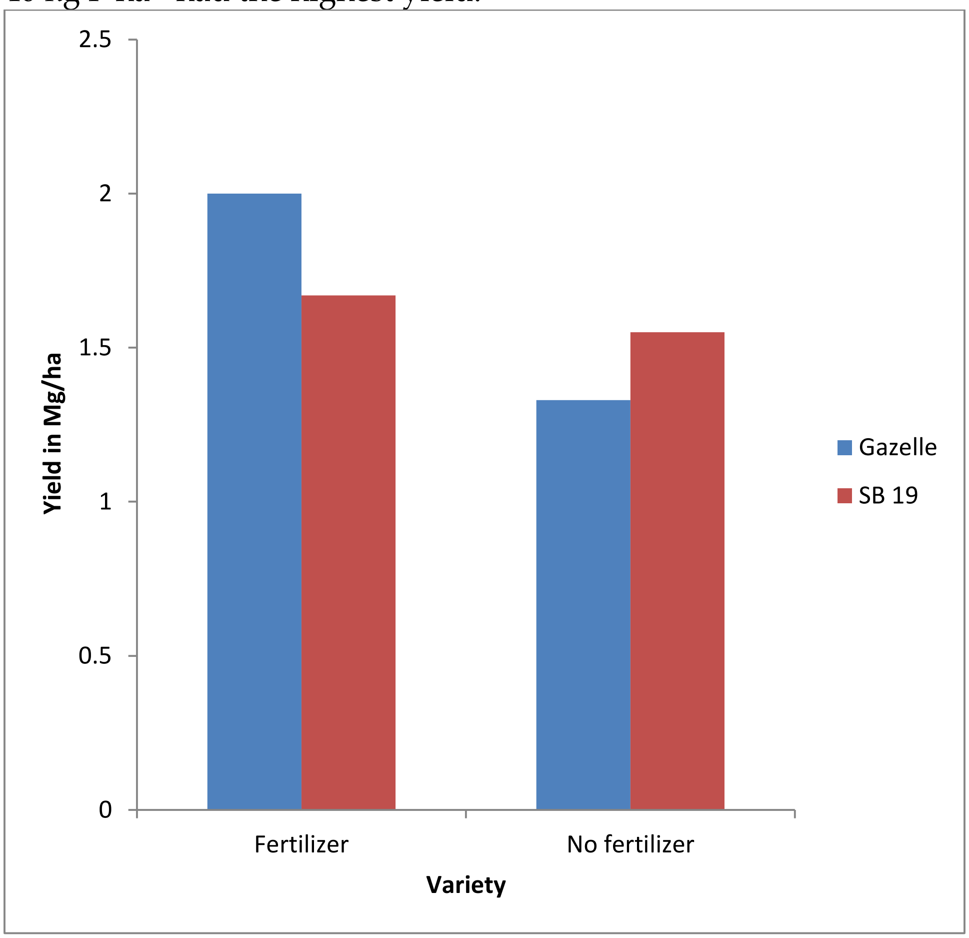

Figure 1: Graph on yields SB 19 and Gazelle with fertilizer and no fertilizer

variety	Fertilizer	No fertilizer
Gazelle	2 Mg/ha	1.33 Mg/ha
SB 19	1.67 Mg/ha	1.55 Mg/ha

DISCUSSION

There was a significant different in plant height of the two varieties in both seasons. SB 19 being taller than gazelle with a mean plant height of 61.3cm (Table 2). Application of TSP increased nutrient supply which enhanced vegetative growth, affecting plant height and yields (Umoetok et al., 2007). The present findings were in agreement with the result of (Bothe et al. 2000) who reported that the application of phosphorus at 75 kg ha-1 enhanced the plant height at highest value. (Maurya and Rathi 2000) also found the positive effect of P on the plant height of soybean. P fertilizer might have supplied P which enhanced N uptake and microorganism's development, therefore mineralization.

There was significant difference between the numbers of pods per plant of the two varieties during SR 2015 season and SB 19 having the highest number of pods (Table 2). Application of fertilizer led to increase of the number of pods per plant in both varieties. These findings were in agreement with (Reddy and Giri1989) who reported that phosphorus application at 20 kg P ha-1 increased the pod yield of soybean. Similar results were also found in soybean by (Jana et al. 1990) and (Singh and Bajpai1990).

There was significance difference between the weights of 100 seeds of the two soybean varieties. Gazelle had the highest with 19.21 grams. Application of fertilizer led to increase of the weight of 100 seeds.

There was no significance difference between the yields of the two soybean varieties. Gazelle had slightly higher yields than SB 19 (Table 2 and Table 4). There was an increase of yields of the two varieties in the two seasons. These results are in agreement with the findings of (Maurya and Rathi 2000) who reported the increase in grain yield of soybean with the application of P .There was no significant (0.3811) interaction between treatment and variety on yields of soybean. Application of TSP increased nutrient supply which enhanced vegetative growth, affecting plant height and yields (Umoetok et al., 2007). P fertilizer might have supplied P which enhanced N uptake and microorganism's development, therefore mineralization.

CONCLUSION AND RECOMMENDATION

Gazelle had a higher Stover yield than SB 19. Gazelle was better in terms of yields than SB 19. In terms of plant height and number of pods per plant SB 19 was better than Gazelle. In conclusion Gazelle outweighed SB 19 in terms of production.

Farmers need to be applying Triple super phosphate (TSP) at rate of 40 kg P ha^{-1} for increased yields regardless of the variety in question.

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8.2 A comparative analysis of the determinants of gross margins from African Indigenous Vegetables in semi-arid and humid rural areas of Kenya

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ABSTRACT

This study assesses the economic returns accrued from production of African Indigenous Vegetables (AIVs) in rural semi-arid and humid areas of Kenya. Multi-stage sampling method was used to select 567 farmers from Busia, Machakos and Nyamira. Data collection was done using a semi-structured questionnaire through Open Data Kit (ODK). Analysis was done through descriptive statistics, analysis of variance (ANOVA), gross margin analysis and a multiple regression. The very humid Nyamira registered the highest gross margin per acre per annum (Ksh. 437, 231), followed by humid Busia (Ksh. 171, 651). Semi-arid Machakos registered negative gross margins per acre (Ksh. -55, 726). ANOVA revealed that gross margins were statistically different across the regions at 5%. In Busia, the gross margins were significantly influenced by number of AIVs grown for commercial purposes, household head's years of schooling,

AIVs diversity, contract farming and market participation. In Nyamira, gross margins were significantly influenced by the distance to a water source, gender of household head, on-farm crop diversity, contract farming and AIVs diversity. In Machakos, household size, area under AIVs production, distance to nearest tarmac road, AIVs diversity, and primary occupation significantly influenced gross margins. Diversity of AIVs was the only factor that influenced gross margins in all the three regions. This study concluded that the region where AIVs are produced influence gross margins, hence the need for region-specific policy interventions.

Key words: African Indigenous Vegetables, gross margins, OLS, ODK, Kenya.

INTRODUCTION

AIVs are vegetables that have had their original habitat in Africa (Gockowski et al., 2003). The vegetables have a wide range of advantages over exotic vegetables. Some of the advantages are; easy availability, high nutrition value and high resistance to pests and disease (Ayanwale et al., 2011; Onim and Mwaniki, 2008). Over 210 AIVs species have been identified in Kenya (Maundu, 1996). These species serve different purposes in various areas in the country. For instance, Kimiywe et al. (2006) observed that consumers attach medicinal value to AIVs in Nairobi. In Uasin Gishu, Mwamburi (2003) noted that AIVs are consumed due to the belief that they can cure many diseases such as stomach disorders, malaria, and ear and eye problems. The vegetables also contribute directly to the economy since they form part of the Horticultural Sector which earns about 36% of the Agricultural Gross Domestic Product (GDP) (GoK, 2012). Production is dominated by small scale farmers, mainly women in rural areas for subsistence purposes (Abukutsa et al., 2005; Abukutsa, 2003). However, due to increased awareness about the benefits of the AIVs, there has been increased demand for the vegetables (Virchow, 2008). Consequently, production, and marketing has spread to urban areas, like Nairobi and its surrounding (Irungu et al., 2007). This has led to AIVs shifting from being grown for subsistence to being cash crops (Ojiewo et al., 2013).

Development of markets for AIVs provides an opportunity that can be utilized to reduce poverty and ensure nutrition security among the poor. Various studies that have looked on agricultural commercialization particularly (Beatrice and Anna, 2014; Rao and Qaim, 2011; Pingali and Mark, 1995) agree that commercialization, which is marked by more input and output market participation (Nepal and Thapa, 2009) improves the well-being of the farmers. Evidence from other countries such as Bangladesh has shown that vegetable production, mostly indigenous vegetables has improved livelihoods in the country (Wannasai and Shrestha, 2008; Rahim et al., 2007). This is not the case in Kenya since areas well known for the production of AIVs specifically Western and Eastern Kenya register the highest malnutrition and poverty levels (KIPPRA, 2013). It has not been empirically proven if the scenario persists due to low revenues from AIVs, or high production costs associated with AIVs production, hence this study.

MATERIALS AND METHODS

This study was carried out in Nyamira, Busia and Machakos. The areas were purposively selected based on various criteria, namely; history of AIVs production, AIVs diversity, proximity to Nairobi and agro ecological conditions, where Nyamira and Busia represent humid regions and Machakos represent the semi-arid area.

Multi-stage sampling was used in this study due to its appropriateness when the population is scattered over a vast geographic area, and precision in hypothesis testing (Allen et al., 2002). This approach has been used in studies like (Gotor and Irungu, 2010; Wanyama et al., 2010; Kibet et al., 2009) where it was not possible to get a sampling frame. A minimum sample of 384 arrived at using the Cochran approach (Cochran, 1977), was later adjusted to 537 as suggested in Israel (1992) to cater for farmers not contacted and non-response. Nevertheless, 567 respondents were interviewed following budget flexibility.

Data analysis involved assessment of gross margins, analysis of variance and a multiple regression. Gross margins were arrived at after deducting variable costs as explained in Oseni and Aledwale, (2013). Labor costs were calculated using the market price for labor (Fox et al., 2005) and man hours spent. The hours were aggregated according to Braun (1991) and appropriate labor equivalences according to Abdulahi (1990) were used in cases where women and children provided labor. Factors influencing the gross margins were analyzed using multiple regression since it allows for discrimination between the influences of the exogenous variables on gross margin. The data used in this study fulfilled the requirements for OLS (Gujarati, 2003).

3. Results and discussions

The overall gross margin was Ksh. 174, 353. Nyamira had the highest gross margin per acre (437, 231) compared to Busia (171, 651) and Machakos (-55, 726) (see table 4). The mean gross margin for Machakos was statistically different from those of Busia and Machakos at 5%. The high total earnings per acre as well as high gross margins in Nyamira may be attributed to high yields in the region as a result of relatively high input utilization as seen from the high expenditure on input in Nyamira.

Labor costs formed the largest portion of the production costs in all the three regions mainly because vegetable production is labor intensive (Lumpkin and Weinberger, 2005), and valuation of own resources like family labor in this study. Labor productivities were statistically different at 5% across the three areas with Busia having the highest labor productivity (131) compared to Nyamira (73) and Machakos (-34). The main cause for higher labor productivity in Busia might be attributed to availability of other agricultural activities options in the county. The negative labor productivity in semi-arid Machakos is mainly associated with low yields due to low input utilization in addition to lack of alternative income sources.

Table 4 shows the factors influencing gross margin generally in the three areas.

For the very humid Nyamira, Distance to water source and Number of crops grown negatively influenced gross margins whereas Diversity of AIVs during the short season, Gender of household head and Contract farming had a positive influence. Longer distances to water sources impair practices such as irrigation hence increasing production risks. Similar findings on the negative correlation between gross margins from vegetables and distance to water sources have been made by Mwaura et al. (2013) and Kundu et al. (2010).

Growing many crops on the farm translate to more competition for resources by the crops hence the negative influence on gross margins. Notwithstanding, a wider diversity of AIVs grown had a positive correlation with gross margins as the farmer is able to spread both production as well as marketing risks. This means that specialization in production of AIVs would result to an increase in the gross margins accrued by the farmers. Contract farming also increases gross margins as it has been observed in other studies such as Rao and Qaim (2011) and Miyata et al. (2009) since it reduces transaction costs and marketing risks, and facilitates access to technical support by farmers (Mwaura et al., 2013; Ngugi et al., 2007).

Being a female farmers as was found to reduce economic returns accrued from AIVs as was also observed by Mwaura et al. (2013) due to the facts that; male farmers are more likely to participate in markets (Bellemare and Barrett, 2006), and control the household resources and even dictate how the resources are allocated (Jecknoniah et al., 2013) making them more likely to use better and more inputs.

In the humid Busia, gross margins were positively influenced by, Diversity of AIVs during the short season, Number of varieties grown for commercial purposes, Group membership, Credit access, Contract farming and Selling of AIVs, and negatively by Education years of the household and salaried employment.

Education years of the household head had a negative influence on gross margins. The finding tarries with what Mwaura et al. (2013) found that learned people will tend to pursue other activities other than production of AIVs. Therefore, training on the potential the vegetables have to generate income might be a viable way of making AIVs production attractive even to the learned people.

The positive influnce of selling AIVs (market participation) on gross margins may be attributed to the fact that market orientation promotes input utilization which in turn increase yields. This finding agrees with Bellemare and Barrett (2006) who observed that market participation increases farmer welfare. Group membership on the other hand increases farmers' bargaining power such that farmers can sell to channels with more returns (Panda and Sreekumar, 2012) and also improve access to credit and information, and reduces transaction and transport costs (Fischer and Qaim, 2012; Ngugi et al., 2007), factors which increase the returns accrued from production of AIVs. The influence of contract farming, number of varieties grown for commercial purposes and diversity of AIVs is as in the explanation above for Nyamira.

Income diversification (salaried income) through involvement in off farm activities influence gross margins from AIVs positively since farmers who do not depend on agriculture are likely to earn higher incomes than their counterparts solely depending on agriculture (Janvry and Sadoulet, 2001). Higher income among farmers is associated with higher market participation (Rao and Qaim, 2011; Boughton et al., 2010) and also relatively higher input utilization hence high gross margins.

For semi-arid Machakos, Household size, Area under AIVs, Log distance to tarmac, Number of crops grown negatively influenced gross margins whereas Diversity of AIVs grown during the dry season and Primary occupation influenced gross margin positively. The negative influence of household size on gross margin may be due to the fact that larger households reduce the quantity of vegetables sold in markets as was observed by Otieno et al. (2009).

The negative correlation of gross margins with area under AIVs agrees with Haggblade et al. (2010) that large farms tend to yield low returns per hectare of land per year compared to small farms. The inverse relationship between farm size and returns may be attributed to the productivity of the land, amount of input requirement and market failures (Barret et al., 2010; Lamb, 2003). In addition, production of AIVs is labor intensive and as such an increase in the area would require hired labor where family labor may not be adequate. Consequently transaction costs on labor supervision will increase (Poulton et al., 2010), resulting to less gross margin and low input productivity. The inverse productivity relationship of AIVs with land dictate a proportionate increase in inputs required for the production of the vegetables for farmers to gain proportionately from the land increase (Boughton et al., 2010).

Long distance to tarmac road results to low gross margins due to impaired market access and reduced group membership (Fischer and Qaim, 2010). Distance to tarmac road may also influence the availability of inputs, and thus reduce/increase input costs. Davis et al. (2010) observed that farmers who were far away from tarmac roads had a low participation rate in farmer field schools. These farmers were found to have not only low productivity but also low incomes. The effect of diversity of AIVs and the number of crops grown is as in the explanation for Nyamira.

Diversity of AIVs grown during the short season was the only significant variable having the same influence in all the three regions. The importance of having a large AIVs diversity on gross margin is as been discussed earlier.

TABLES

Table 1: Analysis of AIVs gross margin

Variable	Busia (n=190)	Nyamira (n=177)	Machakos (n=200)	Overall (n=567)
Average total earnings/acre	310, 493 [a]	980,174 [b]	30,213 [a]	420, 683
Average labor cost/acre	106, 776 [a]	439, 548 [b]	76, 310 [a]	199, 910
Average fertilizer cost/acre	1, 254 [a]	10, 125 [b]	172 [a]	3, 641
Average manure cost/acre	8, 224 [a]	23, 093[b]	5, 375 [a]	11, 860
Ave. Planting material /acre	18, 798 [ab]	26, 880 [b]	3, 063 [a]	15, 770
Average pesticide cost/acre	622 [a]	36, 100 [b]	641 [a]	11, 704
Ave. Transport cost/acre	3, 148 [ab]	6, 198 [b]	325 [a]	3, 104
Ave. production cost/acre	138, 842 [a]	542,943 [b]	85, 939 [a]	246, 329
Average gross margin/acre	171, 651 [a]	437,231 [b]	-55,726 [a]	174, 353
Ave. gross margin/unit labor	131 [c]	73 [b]	-34 [a]	55

Source: Survey data, 2014

Note: The gross margins are in Kenyan shillings (Kshs 95 were equivalent to 1USD$ at the time of survey). The letters account for statistical difference in the means. Same letter across any two or all the three regions means that there is no significant statistical difference in the mean of the variable at 5% significance level.

Table 2: OLS regression results for each of the study regions

	Busia (n =190)		Nyamira (n= 177)		Machakos (n=200)	
Variable	β	P value	B	P value	β	P value
Household size	0.0492	0.303	0.1109	0.169	-0.2516	0.004**
Distance to water source	-0.0576	0.800	-1.2062	0.000***	-0.0709	0.402
Area under AIVs	-0.8821	0.444	2.7956	0.332	-1.0968	0.000***
Irrigation use	0.4458	0.162	0.3608	0.254	0.3843	0.509
Fertilizer use	0.3869	0.281	0.1227	0.691	-0.4475	0.392
Pesticide use	-0.0948	0.766	0.3257	0.555	0.4338	0.262
Gender	-0.1094	0.743	0.8854	0.048**	-0.2463	0.623
Log distance to tarmac	-0.0764	0.709	-0.0189	0.815	-0.3355	0.022**
Number of commercial variety	0.2435	0.006**	0.1031	0.539	0.4540	0.278
Number of crops grown	-0.0375	0.710	-0.1926	0.088*	-0.2772	0.085*
Education years	-0.0737	0.029**	-0.0184	0.667	-0.0013	0.981
Group membership	0.5764	0.068*	0.0530	0.934	-0.0143	0.977
Diversity of AIVs short season	0.3546	0.000***	1.3710	0.000***	1.1774	0.033**
Contract	1.2541	0.024***	2.3993	0.001***	-0.3396	0.891
Selling of AIVs	1.2054	0.000**	0.4992	0.191	0.3199	0.431
Credit access	0.5451	0.083*	0.0369	0.924	0.3182	0.416
Land AIVs squared	0.5652	0.481	-2.3704	0.640	0.0898	0.044**
OCU= Salaried employment	-0.0144	0.969	0.2615	0.559	0.1852	0.737
OCU=Casual worker	1.2896	0.130	0.3737	0.450	2.1763	0.000***
Retail business	0.1947	0.597	0.0541	0.899	0.1787	0.733
Constant	-0.6280	0.216	-2.3321	0.005***	-0.0714	0.947
	No. Observations	190	No. Observations	177	No. Observations	200
	F(20, 169)	13.18	F(20, 156)	6.53	F(20, 179)	4.35
	Prob>F	0.0000	Prob>F	0.0000	Prob>F	0.0000
	R^2	0.3857	R^2	0.4278	R^2	0.3270
	Root MSE	1.7189	Root MSE	1.8985	Root MSE	2.3741

4. Conclusions

This study has shown that the income generation ability of AIVs depends on the region they are grown. The regions are characterized by different environments which influence the kind of production practices used hence yields, and proximity to markets which influence farmer's decision whether to participate in output and/or input markets. Therefore, area specific interventions for promotion of AIVs production and marketing should be pursued.

For the humid Busia, the institutional factors for instance farmers' organization into groups, credit access and contract farming play a major role in enhancing economic returns from AIVs. This therefore calls for the county government and other organizations concerned with the promotion of AIVs to facilitate, and ease access to credit. Measures for instance, input subsidy, and promotion of table banking may provide viable options. Farmers should also be encouraged to participate in AIVs markets in order to improve their incomes through interventions such as construction of proper selling and collection points, and linking the farmers to markets for instance through contract farming.

For the very humid Nyamira, intensification practices such as irrigation are recommended and provision of piped water to reduce distance to water sources. For the semi-arid Machakos, increase in land under AIVs has to be accompanied with a similar increase in utilization of inputs in order to gain proportionately from the land increase. Therefore strategies like input provision by the county governemnt and other actors should be sought for so as to increase returns from the vegetables. Birth control may also help in checking household sizes to enhance market participation.

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8.3 Determinants of Intensity of Participation in Avocado Producer and Marketing Groups in Murang'a County, Kenya

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ABSTRACT

This study analysed the determinants of intensity of participation in avocado producer and marketing groups (APMGs) in Murang'a County, Kenya. Intensity of participation would offer insights on member commitment and free riding to the APMGs. Member commitment in group marketing is critical to planning and implementing production and marketing functions in order to achieve successive collective marketing. Otherwise

the groups may become dysfunctional or even collapse. The number of group meetings attended, quantity of individual sales made and amount of annual contributions made were used as proxies for member commitment. A total of 110 members were sampled proportionately to the group size. The data was collected using a structured questionnaire then analysed using Double Hurdle model in STATA 13. The results revealed that the ideal group size should constitute of 14 to 16 members for optimum participation. Farm size, membership density, group age, trust index, group size, homogeneity index, decision making index, fines existence and provision of free inputs were also key determinants of intensity of participation in the APMGs. Policy implications drawn by this study emphasizes on the importance of the smaller group size, decision making index, trust and the role of social norms and values in enhancing member commitment and participation in collective initiatives. The notable policies will serve to facilitate success in collective marketing and longevity of the groups.
Keywords: *Collective action, Avocado Producer and Marketing Groups, intensity of participation, free riding, Double-Hurdle model*

INTRODUCTION

Collective actions through producer and marketing groups is one of the interventions adopted to enable the smallholders address high transaction costs and other market imperfections and contend with modernization of agri-product markets (Shiferaw *et al*., 2009). The smallholders in Kenya are the major actors constituting up to 80% in agricultural sector. They form an integral component of backward and forward linkages to other economic sectors besides their contribution to rural employment and food supply which is critical to transform the rural economy (GoK, 2010). Despite this, smallholders face challenges like high transaction costs, coordination failure, weak institutions, lack of/asymmetric information, reduced government investments coupled with the recent globalization of agri- commodity markets (Poulton, 2014; Wanyama, 2014). Consequently the smallholders are exposed to market risks, diseconomies of scale and lack of competitive advantages (Shiferaw *et al*., 2009; Poulton, 2014). It is against this backdrop that producer and marketing groups have gained popularity to empower farmers to consolidate their resources to achieve scale economies, competitive advantages, and meet demands of continuous supply and larger volumes consistent with stringent quality and standards required (Poulton, 2014; Wanyama, 2014).

Research shows that marketing through farmer groups increased members' total annual income up to 27% and 16% from bananas and French beans respectively (Fischer and Quaim, 2014; Korir *et al*., 2015). Additionally, farmer groups enhanced marketing performance in Tanzania (Barham and Chitemi, 2009), better prices in Costa Rica and high profits as a result of quality standards and consistent bulky export marketing of coffee in Brazil (Wollni and Zeller, 2006). Despite this, empirical evidence shows that the producer and marketing groups are either dysfunctional or are not sustained long enough to achieve members' interests but end up disintegrating (Fischer and Quaim, 2014; Barham and Chitemi, 2009).This may be attributed to free riding. For successful collective action to be realised in agricultural marketing, better planning and implementation of production and marketing functions, enforcing contractual agreements and conflict resolutions are critical. To achieve this, member commitment and contributions in various group activities is critical to achieve the perceived common goal and hence viability of the groups in the long run. Therefore, the objective of this study was to analyse the determinants of intensity of participation in collective action using an example of avocado producer and marketing groups (APMGs) in Murang'a County, Kenya.

Several studies analysed the intensity participation and free riding in collective action. One study analysed extent of free riding in terms of time and money contributed which assumed a categorical variable (Vorlaufer *et al*., 2012), quantity of collective sales (Mukundi *et a*l., 2013), quantity of collective sales made and the number of meetings attended (Fischer & Quaim, 2014). However, still exists a dearth of empirical evidence on determinants of intensity of participation in producer and marketing groups. This study therefore addressed the gap by assessing how individual characteristics, group characteristics and policy and institutional factors influence the frequency of group meetings attendance, amount of annual contributions besides the quantity of sales made collectively. Policy and practices are further discussed in the last section.

Material and Methods

Study area: The study was conducted in Murang'a County, Kenya. Murang'a County government pilots collective action in smallholder agricultural marketing. However, avocado fruits have received renewed attention owing to the area's potential to produce avocadoes with high oil and wax content. In addition to that, there is ready domestic and export markets (Kakuzi, Olivando and Vegpro companies). The export companies contracts APMGs which are legally registered through Avocado Growers Association of Kenya (AGAK) to sell their avocadoes collectively at designated collection centers.

Data collection and analysis: The data was collected using a pre tested questionnaire from the 110 proportionately sampled group members. The double hurdle model was used for the analysis. The model assumes that households make two sequential decisions which are modeled using different variables. First, decision to participate, in this case is whether a member was involved or not in group meetings, annual contributions and group sales. Secondly, decision on intensity of participation which took a value denoting the number of meetings attended quantity of group sales in proportion to the total marketable surplus and amount of group annual contributions. The parameters were then estimated using Stata version 13.

RESULTS AND DISCUSSION

3.1 Determinants of intensity of participation in APMG activities

Table 1 shows the results for the determinants of participation APMG activities. The farm size had a positive influence on intensity of participation in annual contributions, quantity of sales and number of meetings. Large farm sizes have high incentives because of bulky production which outweighs costs of participation in group as a result of scale economies (Mukundi et al., 2013, Fischer & Quaim, 2014)). A unit increase in trust index increases the amount of annual contributions made by 65.7% points. Trust serves to enhance individual commitment, coordination, and cooperation among group members. Moreover, trust among the actors reduces the risk factors hence they are bound by mutual obligation and reciprocity (Vanni,2014). In regard to group age, older groups may have stronger ties associated with shared norms, trust and values unlike newer groups with greater uncertainty of reciprocity internal cooperation (Vorlaufer et al., 2012, Korir et al., 2015 and Markelova and Meinzen, 2009).The effect of membership density was positive for the amount of annual contributions and share of group sales. Membership densities are an avenue through which social capital is accumulated. Social capital facilitates to minimize opportunistic behaviour, dissemination and sharing of information and collective decision making ((Markelova and Meinzen, 2009). Fine existence had significant ($P<0.05$) and positive effect on the share of annual contributions made and number of meetings attended. Fines enhance accountability and compliance within the group's crafted rules. On the other hand, each additional unit of free input, increases share of annual contributions made to the group by 86.3%. Free inputs act as inducements to members to intensify participation in group activities (Markelova and Meinzen, 2009).

An increase in homogeneity index by one unit increased the number of meetings attended by 58%. This is in view that, groups with members of similar social, cultural, political or economic characteristics are more stable and cohesive (Markelova and Meinzen, 2009). In regard to group size, each additional group member decreases the individual quantity of collective sales and number of meetings attended by 2.1% and 0.2% respectively. This upholds the findings of Fischer (2014), Markelova and Meinzen (2009) and Korir (2015) that unlike larger groups, smaller groups are more cohesive which enhances coordination and easier monitoring of other members hence reduced incentives of free riding.

Table 14: Double Hurdle results: Factors influencing intensity of participation in group activities

	Amount of annual contributions				Quantity of group sales				Number of meetings attended			
	Coeff.	Std. Error	p-value	Marginal Effects	Coeff.	Std. Error	p-value	Marginal Effects	Coeff.	Std. Error	p-value	Marginal Effects
Farm size	0.478*	0.022	0.037	0.015	0.110**	0.411	0.008	0.759	-0.245	0.024	0.297	-0.047
Trust index	0.836**	0.367	0.001	0.657	0.296	0.529	0.577	0.965	0.386	0.370	0.299	0.033
Group size	-0.004	0.009	0.662	-0.001	-0.235***	0.005	0.000	-0.021	-0.003**	0.001	0.002	-0.002
Gender	0.092	0.078	0.243	0.031	-0.686	0.119	0.567	-0.005	0.250	0.082	0.759	0.030
Group age	0.015**	0.004	0.001	0.002	0.199**	0.005	0.001	0.018	0.004	0.044	0.916	0.002
Off farm income	0.022	0.057	0.695	0.283	-0.093	0.104	0.372	-0.957	0.030	0.607	0.620	0.062
Homogeneity index	0.003	0.002	0.136	0.072	0.247	0.352	0.486	0.227	0.549*	0.216	0.012	0.580
Membership density	0.069*	0.027	0.013	0.005	0.148**	0.049	0.003	0.118	0.016	0.028	0.565	0.002
Free input	0.202*	0.096	0.037	0.863	0.059	0.127	0.646	0.104	0.078	0.984	0.426	0.036
Decision making index	0.734**	0.208	0.001	0.023	1.803***	0.351	0.000	0.184	0.862***	0.219	0.000	0.826
Fine existence	0.191**	0.661	0.005	0.058	0.001	0.113	0.994	0.089	0.187**	0.069	0.007	0.009
Timely payment	-0.125	0.101	0.220	-0.325	-0.119	0.123	0.336	-0.055	-0.246	0.138	0.076	-0.519
Constant	-0.648*	0.323	0.047	-0.007	0.313	0.572	0.586	0.821	0.296	0.320	0. 356	0.930
Model Summary												
No. of observations	137				137				137			
LR χ^2 (11)	170.14				164.82				140.35			
Prob > chi^2	0.0000				0.0000				0.0000			
Pseudo R^2	0.6581				0.6820				0.6250			
Log likelihood	-44.189				-38.428				-67.208			

*, ** and *** denotes significance levels at 5%, 1% and 0.1% respectively.

Decision making index was strongly associated with the intensity of participation in the three measured group activities. Decision making among the group members fosters internal democracy and among the actors, decision making index facilitates in creating and reinforcing "exploitation-free" contractual agreements between group members and export agents.

3.2 Group Size and Intensity of Participation in APMG Activities

To estimate the relationship between group size and quantity of sales made through the group, bivariate non-parametric regression was used in Distributive Analysis Stata Package (DASP). This method was used to estimate the local derivative of the group size with respect to the quantity of group sales without having to specify the functional form linking them. Regression with the non-parametric curves module was performed with Nadaraya-Watson approach. This approach allows observations to enter and exit the model smoothly by selecting the bandwidth, which controls the degree of smoothing (Araar A. *et al.*, 2013). Figure 1 shows the relationship between group size and the individual sales made through the group.

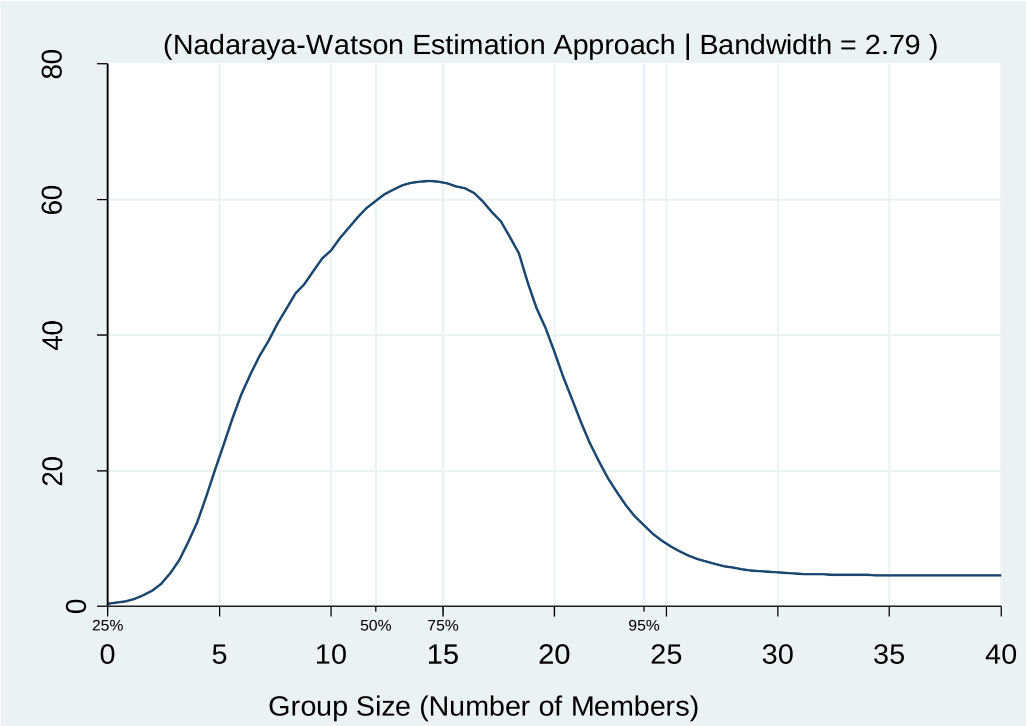

Figure 1: Relationship between group size and group sales

The findings reveal that the ideal group size should constitute of 14 members for optimum intensity of participation in the group sales. Below 14 members, despite the stronger ties, the smaller group size implies lower economies of scale. On the other hand, although groups of more than 14 members enjoy economies of scale, they tend to have weaker social cohesion.

This promotes the incentives to free ride due to inability to monitor the behavior of peers.

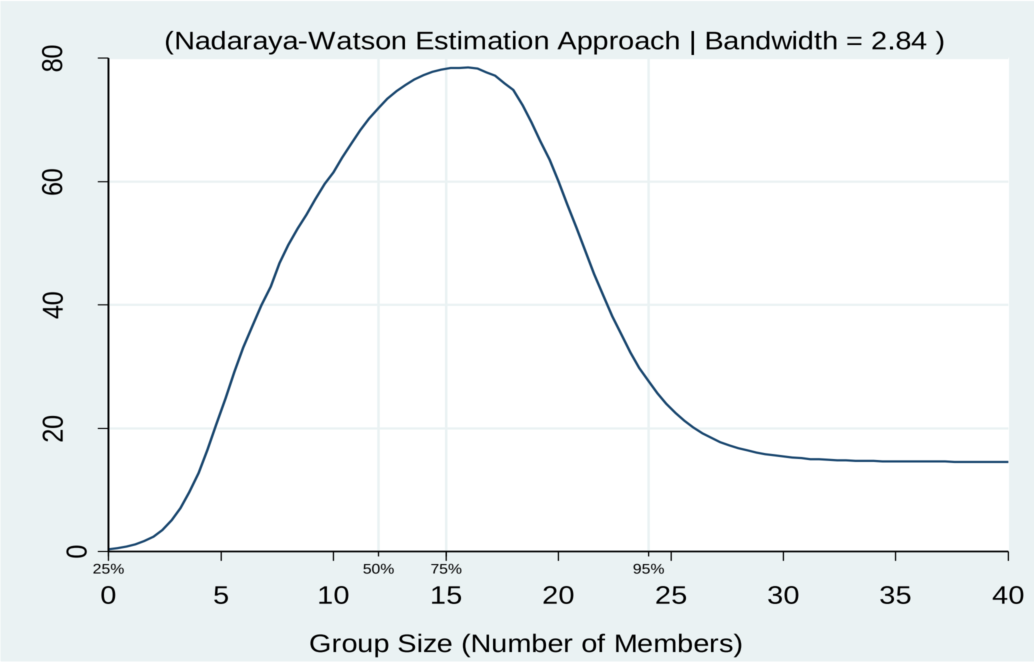

Figure 2: Relationship between group size and group meeting attendance

Figure 2 shows the relationship between group size and number of meetings attended. Adding an extra group member results to increase in number of meetings attended. However, this increase is up to the point where the group size is about 16 members. Additional group members enhance the members' voice and solidarity due to enhanced interpersonal interactions which strengthens their social ties (Korir, 2015). Beyond 16 members, for each additional member results to a decline in the number of meetings attended. This may be explained by the weaker social cohesiveness and difficulties in monitoring other members' behavior which increases the monitoring costs which also makes larger groups, in this case, of more than 16 members not ideal.

5. Conclusion and Policy Implications

The results revealed that a group size of 14 to 16 members is ideal for optimum participation. Membership to other groups and networks, democratic participation in group functioning, similarly in members' identity, trust, imposing fines to non-compliant members and provision of free inputs emerge as key determinants of intensity of participation in the avocado producer and marketing groups.

Policy implications drawn from the study enhance strategies to intensify participation in collective action for successful collective marketing and sustainability of the groups in the long run. First the group size should constitute 14 to 16 members. Strategies to foster democratic participation of members in group functioning, transparency and accountability systems are vital to assure members on governance and financial management aspects. Furthermore, the existing extension policies in collaboration with the respective actors need to identify and integrate the strategies that recognize the role of the social norms and values in their training and dissemination of knowledge. Finally, the contracting export agents should also honor their contractual agreements to heighten trust from the groups.

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9. Parallel Session 8: Crop Management, Biotechnology and Climate Change

9.1 Evaluation of the effect of (*A. indica*, *A. sativum* and *L. camara*) leaf extracts on root-knot nematode management on tomatoes in Mwea-East, Kenya.

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Abstract
Tomato (*Solanum lycopersicum* L.) is an annual sub-tropical vegetable grown in Kenya for both domestic and export market. Its production in Kenya has suffered a major blow due to the high disease incidences caused by nematodes. Root-knot nematodes are known to cause greater damage to vegetables. The current methods of nematode control involve use of chemical nematicides but the major concerns have been the arising problem of pollution as a result of the use of chemicals and development of nematicide resistant strains arising from excessive application of chemical nematicides. This makes it important to research on new and effective methods of nematode management that are less risky to the environment. The objective of this study was to evaluate the effect of the plant extracts of *A. indica*, *A. sativu*m and *L. camara* on root-knot nematodes affecting tomatoes in Mwea-East, Kenya. Field experiments were done to determine the efficacy of the extracts on the control of *Meloidogyne* spp. Treatments included *A. indica, A. sativum* and *L. camara* extracts, a commercial nematicide, vydate and untreated control. The experimental design was a completely randomized block design involving five treatments. Data on growth and *Meloidogyne* spp. infestation was collected. All the extracts significantly ($p \leq 0.05$) caused more growth as indicated by the higher shoot height, root length and dry weight when compared to the untreated plants. In the experiments the shoot height and root length showed significant difference ($p \leq 0.05$) with *L. camara* treatment recording the highest values. Galling index, egg mass index, final J2 in the soil and the reproductive factor differed significantly among the treatments ($p \leq 0.05$). The treatment with *L. camara* gave the highest yield and greatly reduced nematode damage. This results show that plant extracts are an alternative to chemical nematicides that cause pollution to the environment.
Keywords: Tomato; Plant extracts; Root-knot nematode; Growth.

INTRODUCTION
Tomato (*Solanum lycopersicum* L.) is an annual sub-tropical vegetable. Its origin is in the Southern America Andes. The crop was introduced in East Africa by the colonialists in early 1900 (Wamache, 2005). It was first used as food in Mexico and these later spread to other parts of the world following the colonization of the Americans by the Spanish. Tomatoes grow well in warm conditions and its varieties are now found growing in many regions of the world sometimes in greenhouses in regions that have very cool climates. Uses of tomatoes may range from its use as an ingredient in dishes, as a salad, a drink or as a sauce. There are considerations of

tomato to be a vegetable for culinary purpose even though it is classified as a fruit botanically (Smith, 1994).

Many plant parasitic nematodes attack tomato plants growing in different regions. Tomato plants are known to be the most favorable hosts for root-knot nematodes (Dropkin, 1980, Dnyaneshwar *et al*., 2010). The root-knot nematode groups known to attack tomatoes include the 4 major species of *Meloidogyne* (*M. hapla*, *M. arenaria*, *M. incognita* and *M. javanica*) and their known races in both indoor and outdoor cultivations (Onkendi *et al*., 2014).

The use of synthetic nematicides has been the common practice in the management of plant parasitic nematodes. The indiscriminate use of these pesticides in nematode control has resulted in environmental pollution, phytotoxicity and nematode resistance (Conway, 1995; Yudelman *et al*., 1998). Some synthetic pesticides are also very expensive and some farmers are not able to buy them (Koon-Hui *et al*., 2010).

The study was therefore done to evaluate on the possibility of plant extracts being used as alternatives for the management of root-knot nematodes in tomatoes. The plant extracts are considered to be more ecologically friendly and do not cause pollution to the environment.

MATERIALS AND METHODS

Study area

The study was carried out in Mwea East, Kirinyaga County, Kenya.

Samples collection and processing

Sampling was done using purposeful sampling method in farms where tomatoes were grown. Samples of diseased tomato plants and soils surrounding the roots were collected from the farmers' fields in Mwea East. A composite sample was obtained by mixing the sub-samples collected from the same farm. For further processing, the composite samples were then taken to the laboratory at Kenyatta University.

Plant extracts preparation

The mature leaves of *L. camara* were collected from Kenyatta University while the leaves of *A. indica* were collected from Garissa- North Eastern region of Kenya due to their high presence. The bulbs of *A. sativum* were bought from the local market in Mwea town. Some of the collected plant materials were brought to the lab for identification by a plant taxonomist. The remainders were thoroughly washed in sterile distilled water to remove soil and other debris. The leaves of *A. indica* and those of *L. camara* were then left to air dry for five days under a shade. A sterile electric blender was then used to ground the dried leaves to powder.

A. sativum bulbs were washed in distilled water that had been sterilized and then taken in an oven for drying. Temperatures were set at 40^0C and left for 48 hours .The dried bulbs were then ground in to powder.

A 100 milliliter of sterilized distilled water was placed in different one litre conical flasks. A 20 g powder of the plant extracts was then added to the stoppered conical flasks and left for 24 hours. After a 24 hour soaking, filtration was done using cheese cloth and the extracts stored in the refrigerator until use. The extracts were considered standard solutions "S" (100% concentration) (Mukhopadhyay and Tiwari, 2001 and Taye *et al*., 2012).

Field and experimental plot preparation

The field experiment was conducted at Vick Agricare Limited Research farm in Mwea East, Kirinyaga County. The initial population of *Meloidogyne* spp. in the field was assessed by sampling soils before application of treatments.

Tomato seedlings for use in these experiments were raised in a nursery. Experimental plots measured 16 m^2. Each plot contained 3 planting rows, each row with 7 plants. There were a total of 21 plants per plot. In each planting hole, 5 g of DAP fertilizer was applied and mixed thoroughly with soil during transplanting. After transplanting, 30ml of each plant extract was applied at each plant station. Vydate was used as the positive control and was applied at a rate of 8 litres/ha while untreated plots served as the negative controls. A completely randomized block design with three replicates was used for the plots. Harvesting commenced two months after transplanting. After each harvest, the fruits were weighed using an electric balance scale. In order to determine the total yield, the total number of fruits per plant was also recorded. Ninety (90) days after transplanting, the experiments were terminated and data on tomato growth and *Meloidogyne* spp. reproductive parameters recorded.

Measurement of plant growth parameters

During termination of the field experiment, shoot height was measured from the base of the stem (soil line) to the newest apical node. Roots were then separated from shoots. Shoot fresh weight per plant was determined using a weighing balance. All stems and root systems were then oven dried at 60^oC until constant weight was obtained. Root and shoot dry weights were determined separately. Data on fruit weight per block and number of fruits per plant were obtained.

Determination of the galling index

The galling index was determined using the scale of 0 to10 as described by Bridge and Page (1980). On this scale 0 = No galls on roots, 1 = few small galls observed upon close examination, 2 = small galls which are clearly visible while the main root is clean, 3 = numerous small galls observed, 4 = numerous small galls and a few big ones seen, 5 = 25% of the root system galled, 6 = 50% of the root system severely galled, 7 = 75% of the root system severely galled, 8 = no healthy root, but plant still green in colour, 9 = root system completely galled and plant dying, and 10 = plants and roots dead.

Determination of the egg mass index

Egg mass index was done by counting the egg masses in root system. Phloxine B solution (0.15 g/l) was used for staining the egg masses on the roots for period of about 15 minutes (Holbrook *et al*., 1983. Egg masses were counted under a microscope and scored using a scale of 1-9 where: 1 = no egg masses, 2 = 1-5, 3 = 6-10, 4 = 11-20, 5 = 21-30, 6 = 31-50, 7 = 51-70, 8 = 71-100 and 9 = >100 egg masses per root system (Sharma *et al*., 1994).

Determination of the population of root-knot juveniles in soil

The nematode juveniles were extracted from different soil samples collected from the different experimental units using the method suggested by Coyne *et al*., (2007).

Two hundred (200) cm^3 of fine soil was taken and placed on a two layer of serviettes placed on plastic containers with perforations which were then placed on plastic plates on a bench (Nchore *et al*., 2011). Water was then added to the extraction plates until the soil became dump. The set up was then left for 48 hours for the nematode migration to take place. After the period, the contents of the tray containing the nematodes were sieved using a 38 µm mesh into a beaker and allowed to settle. After an hour, the excess water was drained by use of a dropper to make the suspension to 20 ml for each set up. This nematode suspension was used for counting. Counting of the juveniles was done using a compound microscope under low power objective lens (x10). The nematode population was then estimated based on the totals obtained.

Reproduction factor

The nematode reproduction factor (RF) was determined and expressed as Rf = Pf/Pi, where Rf = reproduction factor, Pf = final population of nematode at harvest and Pi = initial J2s inocula.

DATA ANALYSIS

Data collected was subjected to Minitab statistical software program. Variation among the means was established using Analysis of variance (ANOVA). Tukey's HSD was used to separate means where significant differences occurred. Mean values significantly different at $P \leq 0.05$.

RESULTS

Effects of *A. indica*, *A. sativum* and *L. camara* extracts on tomato growth parameters

The results showed that the number of plant leaves and the fruits in all treatments did not differ significantly ($P \leq 0.05$, Table I). *L. camara* and Vydate treatments recorded a higher ($P \leq 0.05$) stem height when compared to the other treatments. The untreated control and *A. sativum* had the shortest plants.

Shoot dry weight, Root length and root dry weight were significantly higher ($P \leq 0.05$) in treatments with *L. camara* and vydate. The lowest values were recorded by the untreated plants.

Effects of plant extracts of *A. sativum*, *L. camara* and *A. indica* on galling index and egg mass index on tomatoes

The results from the experiment showed that, galling index and egg mass index were significantly lower in the treated plants than in the untreated control ($P \leq 0.05$, Table II). The lowest galling and egg mass indices were recorded in plants under vydate and *L. camara* treatments. No significant differences ($P \leq 0.05$) were observed in the galling index of plants under *A. sativum* and *A. indica* treatments (Table II).

Effect of the extracts on the population of juveniles in the soil, reproductive factor and the average fruit yield

The number of juveniles, reproductive factor and the average yields were determined. A significant difference ($P \leq 0.05$) was observed in the treatments for the average yield in the experiment (Table III). Plants treated with *L. camara* recorded a higher yield (P ≤ 0.05) than the other treatments. The lowest yield was with the untreated plants. The number of juveniles in the treatment with *L. camara* was not significantly different from that with *A. sativum* (P ≤ 0.05) however it was lower (P ≤ 0.05) than the untreated control. The value of the reproductive factor was significantly (P ≤ 0.05) lowest in *L. camara* and Vydate, but significantly highest in the untreated control (Table III).

The untreated plants gave a significantly lower (P ≤ 0.05) average yield but different significantly (P ≤ 0.05) in the other treatments with *L. camara* treated plants recording the highest yield (Table III)

Tables

Table I: Mean values for growth parameters of tomatoes grown in the field naturally infested with *Meloidogyne* spp. and treated with extracts from *A. indica*, *A. sativum* and *L. camara*.

Growth parameters of tomatoes treated with different plant extracts and the positive and negative controls						
Treatment	No. of leaves	Stem Ht.	Root length	Shoot dry wt.	Root dry weight	Fruit number
A. indica	45.73±4.29 a	80.87±5.38 b	8.6±0.19c	19.93±0.53 c	7.36±0.28 d	29.80±3.37 a
A. sativum	42.27±3.28 a	76.53±5.0bc	9.73±0.28b	19.77±0.45 c	8.14±0.07c	30.73±4.91 a
UC	56.73±3.35 a	75.47±5.43 bc	8.23±0.33c d	19.31±0.50 d	7.33±0.35 d	26.07±2.63 a
L. camara	56.73±8.28 a	95.60±5.28a	12.73±0.55 a	28.80±1.75 a	9.82±0.22a	40.33±4.94 a
Vydate	30.47±4.9a	92.20±3.42a	10.27±0.30 b	24.13±1.22 b	8.99±0.51a b	32.27±4.64 a
F-value	1.66	3.46	25.46	15.79	6.84	1.58
P-value	0.169	0.012*	0.0001*	0.0001*	0.0001*	0.190

Mean measurement of five replicates (lengths in cm, weights in grams)
Mean values denoted by the same letters are not significantly different at P ≤ 0.05
UC- untreated control.

Table II: Mean galling index and egg mass index on tomatoes grown in the field naturally infested with *Meloidogyne* spp. and treated with extracts of *A. indica*, *A. sativum*, *L. camara* , Vydate and untreated control

Treatment	Nematode parameters taken on tomatoes under different treatments with plant extracts and positive and negative control	
	Galling index	Egg mass index
A. indica	2.53 ± 0.77b	3.4 ± 0.47b
A. sativum	2.73 ± 0.49b	2.4 ± 0.40c
Untreated control	8.07 ±0.52a	5.53± 0.31a
L. camara	2.33 ± 0.83c	2.27 ±0.30c
Vydate	1.46 ± 0.74c	1.87 ±0.41c
F-value	14.90	14.90
P-value	0.0001*	0.0001*

Mean value denoted by the same letters are not significantly different at P ≤ 0.05

Table III: Mean number of Juveniles, reproductive factor and average yields of tomato fruits in the field under treatment with extracts of *A. indica*, *A. sativum*, *L. camara*, Vydate and untreated control

Treatment	Number of Juveniles	Reproductive factor	Average Yields (Kg) per block
A. indica	166.7 ± 18.6b	0.64 ± 0.07b	10.67 ± 1.67ab
A. sativum	140.3 ± 19.4bc	0.54 ± 0.07bc	10.83 ± 2.17ab
Untreated control	360 ±35.5a	1.39 ± 0.14a	7.0 ± 0.58b
L. camara	120.67± 8.67c	0.46 ± 0.03bc	13.0 ± 1.53a
Vydate	52.7 ± 16.6d	0.20 ± 0.06d	8.33 ± 0.33b
F-value	28.54	28.54	4.30
P-value	0.0001*	0.0001*	0.018

Mean measurement of the parameters in three blocks
Mean values denoted by different letters are significantly different at P ≤ 0.05

DISCUSSION

Effect of the plant extracts of *A. indica*, *A. sativum* and *L. camara* on plant growth parameters

The results demonstrated that the plant extracts enhanced plant growth as shown by the increased plant root length, shoot height, number of leaves, dry root and shoot weight when compared to the untreated control.

Plants treated with *L. camara* extracts showed greater enhanced growth and increase in height than the *A. indica* and *A. sativum.* This results support those mentioned by Wondimeneh *et al*., (2013) who observed that application of plant extracts led to an increased plant height when compared to the untreated plants.

The increase in infestation as reflected by the number of galls might be the reason for the reduction of plant height in the untreated control. Distortion of the plant roots and nematode colonization of vascular bundles could reduce supply of nutrients to plants. The galls that are formed on the roots interfere with the functioning of the roots hence hindering important functions like water and nutrients uptake (Sikora *et al.,* 2005).

The botanicals provide a suitable environment for the roots to absorb and utilize the soil nutrients that results in reduced damage caused by nematodes (Abubakar *et al*., 2004).

Shorter plant height was recorded from untreated inoculated control tomato plants. The stunting action of *Meloidogyne* spp. may result in the reduced plant height of the untreated plants. Jinfa *et al*., (2006) has also reported on the reduced plant height and shortness of plants infected with root-knot nematodes.

Fruit number and weight of tomato

Tomato yield per plot increased significantly in the treatments with the botanical extracts when compared to the untreated control. This result supports those reported by Wondimeneh *et al.,* (2013) who demonstrated that the application of botanical extracts including neem and *L. camara* leaf extracts significantly improved the yield of tomato in the field with *L. camara* giving the best results.

The difference in toxicity levels of the different extracts from the plants may be due to their variations in chemical compositions and also their differences in the concentrations of the toxic compounds. This may be the cause of the differences observed in performance on yield and nematode infestation. Maqbool and Firoza, (1996) reported that different plant leaves and seeds extracts act differently on *Helicotylenchus spp.* infested tomatoes.

Effects of the extracts on nematode parameters (population of juveniles in the soil, egg mass index and galling index)

The extracts significantly reduced the population of juveniles in the soil, the galling index and the egg mass index on roots when compared to the untreated plants. The nematicidal effect of the plant extracts could be the cause of the reduced number of motile larvae that penetrates the roots of the plants. This effect of the extracts is believed to act directly on infective J2 larvae.

Agbenin *et al*., (2005) reported that *A. sativum* extract resulted in reduced soil larval populations and also a decrease in the egg mass and galling indices on plant root. The egg mass index of *L. camara* and *A. sativum* was not significantly different from that of chemical nematicide (Vydate). This shows that both were effective in the control of root-knot nematodes infecting tomatoes. This was also reported by Wafaa *et al*., (2013) who noted that castor seed and *A. sativum* aqueous extracts led to a reduction in the egg mass index and the galling index in the roots of tomato. The reduced population densities of the nematodes accompanied by increased growth of the tomatoes shows that the tested plant extracts have nematicidal potentials. The extracts may be toxic to the eggs or the juveniles resulting in reduction in nematode numbers in the soil.

Abdi, (1996) attributed the reduction in the galling index to poor penetration by the J2s and the retardation in their activities like feeding and reproduction. This could be further attributed to plant extracts.

Nematode population at harvest

The nematode count at the start of the field experiment was 260 juveniles /200 cc soil. However, the final population density in the soil at the time of harvest showed that the root-knot nematodes had significantly ($p \leq 0.05$) reduced in the treatments with plant extracts over untreated control. From the results the number of J2s in the soil in *L. camara* and vydate treatments did not differ significantly. These results are similar to those of Wondimeneh *et al*., (2013) who reported that plant extracts from mexican marigold, *Lantana* and bitter leaf leaves at 5% concentration lowered the final nematode density significantly over the untreated control and was comparable with the synthetic nematicide.

Farms with garlic or intercropping garlic with other crops have shown potential in decreasing the reniform nematode population and *M. incognita*. This is attributed to the allelopathic substances contained in garlic or that garlic did not offer the essential elements important in nematode development (Ameen, 1996).

The extracts are believed to contain certain chemicals that possess ovicidal and larvicidal properties that inhibit the multiplication of the nematodes. This could be the cause of the reduction in the final population densities of nematodes in the soil (Agbenin *et al*., 2005).

Qamar *et al*., (2005) reported that the aerial parts of *L. camara* contain chemical substances such as lantanone, oleanolic acid, lantanoside and camaric acid that posses nematicidal properties that work against *M. incognita*.

Ahmad *et al*., (2010) has also reported that various concentrations of *L. camara* leaf extracts have deleterious effect that act against nematodes.

CONCLUSIONS

This study showed that among the different plant extracts tested *L. camara* leaf extract at 5% concentration worked well against the *Meloidogyne* spp. It was able to increase the tomato yield and showed greater potential for use in management of root-knot nematode in tomato plants.

The results of the present study show that extracts from different plant species have varying degrees of antinematicidal effects. The presence of natural phytochemicals in different plants that have antinematicidal effects is a promising option for control of root-knot nematodes.

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9.2 Assessment of sweet melon pollinators grown under field conditions at KALRO-Kabete, Kenya.

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ABSTRACT

Sweet melon, (*Cucumumis melo L.*)is a succulent and extra-sweet fruit demanded by the high-end consumers in Kenya. The fruit is valued mainly because of its high concentration in vitamins and anti-oxidant properties. Sweet melons are produced in the warm areas under field and greenhouse conditions in Makueni and Machakos counties, Kenya. Without pollinator visits, the crops suffers in production. The study was motivated by the limited information about pollination provision in sweet melons grown in Kenya. The purpose of the study was to identify the pollinators of the sweet melons grown in the field. An experiment was set at KALRO-Kabete field plots and observations were made on the flower visitors. The flower handling time amongst three insect visitors, : honeybees, butterflies and hoverflies was recorded using a stopwatch from 8.00am to 4.00 pm. The results of the study showed that the honeybees recorded the highest mean number of visits between 0900hrs and 1600hrs. The honeybees also spent a significantly longer time foraging on the sweet melon flowers as compared to the butterflies and hoverflies, $p < 0.001$. The findings suggest that honeybees contribute significantly to pollination for sweet melons. As such, farmers are encouraged to keep honey bees to assure fruit set and high quality fruits.

Key words; Honeybees, pollinators, pollination, sweet melons

INTRODUCTION

Sweet melon, *Cucumis melo* is vegetable crop economic value that is cultivated in different parts of the world. Traditionally, *Cucumis melo* is perceived to be a dessert plant that originated from Africa and was first domesticated in Egypt as a source of food (Goldman, 2002). The crop belongs to the family *Cucurbitaceae*, and it is cultivated in the warm areas in the tropics. The fruits are a dietary choice for some people because of its Vitamin C, Vitamin E, carotenoids that are known natural antioxidants. Consumers are attracted to the sweetness of the fruits and also the health benefits that come with consumption. In the world, high production of sweet melons is done in the United States, China, Turkey, Mexico and Brazil(Sebastian, Schaefer, Telford& Rennera, 2010).In Kenya production of sweet melons is slowly gaining popularity in the warm areas of Makueni,Machakos, and Garissa (Horticultural Crops Directorate, 2006).Production of sweet melons in the field is challenged by pests and diseases (Goldman, 2002). For example, the common pests that constrain production range from cutworms, whiteflies, Aphids, mites and fruit flies. Common diseases of the crop include powdery mildew, blight, and fruit rot. Faced with these challenges, farmers rely on the use of pesticides to control the pests and diseases (Ascher and Pickering 2011). Essentially, pollination determines fruit set in sweet melons and other cucurbits (Roubik, 1995;Abrol 2011).Researchers in the United States recently covered the impact of systemic pesticides such as neonicotinoids on honey bees. Systemic pesticides have been linked to colony collapse disorder (Ascher and Pickering 2011). Where pollination services are not provided farmers risk losing the entire crop because the unpollinated pistillate flowers end up aborting(Kasina *et al*., 2009). Information about the best pollinating agents for sweet melons in Kenya is still scant even though farmers cultivate the crop on. Because of pollination needs of sweet melons, the present study was conducted with the aim of assessing and identifying the most effective pollinators of sweet melons grown in the field.

MATERIALS AND METHODS

The study was conducted between September and December 2014 and from July to Dec 2014 on an experimental plot at KALRO-Kabete. The site is located Northwest of Nairobi Nairobi 36^{o} 41′ E and 01^{o} 15′S along Waiyaki Way 7 kilometers from the Central Business District.The experiment was laid out using a Randomized Block design. Planting of sweet melon galia variety seeds was done in a plot size of 10 x10 m with a spacing of 1x1 m. Three seeds were sown leading to the germination and development of 2 or 3 plants that were later thinned out to one. Insect visitors on the sweet melon flowers were observed during the day and were collected using a sweep net. Samples of the collected insect visitors were taken to the entomology laboratory for identification. Sampling of the sweet melon flowers was done randomly , and 1 plant was selected in every row of sweet melon plants. Observations of the foraging behavior of insect visitors commenced 2-3 days after the sweet melon flowering. The foraging insects were observed between 0900 and 1600. The number of flowers that were visited was recorded and the time spent on the flowers was taken using a stopwatch. Pollinator exclusion experiment was carried out using the bagging method in which some selected female flower birds were bagged in order to prevent visitation by bees and other pollinating agents. In addition to recording the number and durations of visits, direct observations of foraging behavior on sweet melon flowers was done in the experimental field. Pollen and nectar harvesting by the worker bees was registered based on the foraging activity of each visitor. On maturity the weight of the fruits, size and number of developed seeds were collected and recorded. Data was statistically analyzed using Genstat software version14.

RESULTS AND DISCUSSION

A total of 3 insect species were observed, collected and recorded visiting the sweet melon flowers between 09.00 and 1600. The honey bees recorded the highest mean number of visits to the sweet melon flowers 24.03±5.8as shown in table 1. The butterflies and hoverflies had the lowest mean number of visits during the sweet melon bloom (0.83±0.0). The flower handling time recorded from the three insect visitors showed that honey bees had the highest mean flower handling time 10.06±0.3. The butterflies flowed with a mean flower handling time of 5.0±1.0. The hoverflies had the lowest mean flower handling time of 3.6±0.3 in the two seasons of investigations in the field. A significant difference was observed in the sweet melon flower handling time between the honey bees, butterflies and hoverflies P <.001 as shown in figure 1.

Table i: The mean number of visits ± SEM by honey bees, hoverflies and butterflies on sweet melon staminate and pistillate flowers season 1 and season 2 at KALRO Kabete.

	Mean number of visits (± SEM)		
	Honey bees	Butterflies	Hoverflies
Season 1	17.875±2.3	0.5±0.1	0.25±0.1
Season 2	6.167±1.0	0.33±0.2	0.33±0.2
Totals	24.03±5.8	0.83±0.0	0.58±0.0

Table ii: The mean flower handling time (± SEM) by honeybees, hoverflies and butterflies on open staminate and pistillate flowers in season 1 and season 2 at KALRO Kabete.

	Mean flower handling time (± SEM)			
	Honey bee	Butterfly	Hoverfly	pvalue
Season1	5.16±0.1	3.0±0.0	2.0±0.0	0.022
Season 2	4.9±0.2	2.0±1.0	1.6±0.3	<.001
Totals	10.06±0.3	5.0±1.0	3.6±0.3	

In other past studies on sweet melons and other crops(Squash,Pumpkin,castor bean), results have shown how the foraging behavior of honeybees, their duration of visits and pollen deposition correlate with their pollination success of different crops (Thomson, J. Goodel l,K 2006; Artz, Hsu,& Nault, 2011; Cane, Sampson& Miller, 2011; Rizzardo et al. 2012).The results showed that the honey bees recorded the highest number of visits on the sweet melon flowers. Their highest mean number of visits on the flowers during the bloom suggests that they have a high chance of pollinating the pistillate flowers.The foraging behavior of honeybees observed in the field was more beneficial than that of the butterflies and hoverflies. Worker bees were observed introducing their heads between the stigma or the anther. The honey bees took a longer time foraging on the flowers than the hoverflies and the butterflies. Being the commonest flower visitors on the sweet melons in the field shows the success of honey bees in pollinating the plants. Honeybees foraging behavior and harvesting of pollen from one flower to another makes them effective in pollinating the female flowers. The extended visits by honey bees on the sweet melon flowers were due to the pollen reward they get from the flowers. The increased visitation duration by the honey bees increased their success in pollinating the sweet melons. Manetas and Petropoulou (2000), record that honey bees prolonged visit on flowers is because of availability of nectar, and this increases the probability of pollen being deposited on the female flowers and successful pollination.

In a recent study in Brazil by Ribeiro et al. (2015), the value of honeybees on *Cucumis melo* was determined in an experiment that compared the number of honeybees visiting flowers in plots with different hives. Their findings suggest that the number of honeybee visits on the sweet melon flowers correlates with quantity and quality fruit production. For instance, where there was no hive or 1 hive the effect of honeybee visitation was not strong as compared in the plots where the hives were 2 or 3 thus having a stronger visitation effect.

CONCLUSIONS AND RECOMMENDATIONS

Sweet melons grown in the field benefit from pollination by honeybees that prefer their flowers. The high number of visits made on the sweet melon flowers increases the chances of pollination.

The effectiveness of honeybees in pollinating sweet melons has been shown with fruit set, fruit size and weight. Honeybees are therefore an invaluable asset in sweet melons and other vegetable crops production. Further investigations are needed to determine the impact of other factors such as diseases on their foraging activity and effectiveness in pollination of crops.

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9.3 Assessment of genetic diversity of Kenyan Dolichos bean (*Lablab purpureus*) (L) using simple sequence repeat (SSR) markers

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ABSTRACT

Dolichos bean or Lablab is a multipurpose drought tolerant crop in the family Leguminosae. Its leaves and immature pods are used as vegetables, dry beans as grains and the whole plant is used as fodder. Lablab varietal development in Kenya has been inhibited by lack of information on its genetic diversity. The aim of this study was to assess the genetic diversity of the Kenyan Lablab using simple sequence repeat (SSR) markers with a view to designing a varietal improvement programme. Ten simple sequence repeat primers were assayed on ninety six (96) Lablab genotypes collected from various parts of Kenya. The genotypes were grouped into 15 populations based on place of collection. DNA isolation was done using a modification of the cetyltrimethylammonium bromide (CTAB) method and subjected to polymerase chain reaction (PCR). Expected heterozygosity ranged from 0.23 to 0.46 and on average was 0.38. The average polymorphic information content (PIC) was 0.63. Analysis of molecular variance (AMOVA) showed that 15% genetic variation was among populations and 85% was within populations. Highest *Nei's* genetic distance was between Western and Mwingi populations while lowest genetic distance was between Embu and Meru populations. Cluster analysis separated the 15 populations into two main groups. Narrow genetic variation of genotypes may result during long cultivation history of species as an adaptation to local agro-climatic conditions. Farmers continuously select good seed for planting based on desirable agro-morphological traits such as yield, disease resistance, drought tolerance and earliness in maturity. Molecular markers are scattered throughout the genome and their association with various agronomic traits is influenced by selection pressure. This study indicates that the Kenyan Lablab has a narrow genetic base and highly related. The need to design breeding programs with the aim of broadening the genetic base is of paramount importance.

Key words: Dolichos bean, genetic diversity

INTRODUCTION

Dolichos bean or Lablab bean (*Lablab pupureus* (L.) Sweet) belongs to the family Leguminosae. Its multipurpose uses make it an important species globally (Schippers, 2000). It has primarily been an ornamental annual vine in the United States of America for generations (Stevens, 2012). In India and China, the complete plant is edible (Kala *et al*., 2010). Young leaves are eaten raw in salads and older leaves are cooked like spinach. Flowers are eaten raw or steamed. The large starchy root tubers can be boiled and baked. The immature and dried seeds can be boiled or fried and both the leaf and seed of Lablab are rich in proteins (Kala *et al*., 2010). Lablab is useful as a cover crop and forage (FAO, 2012). Its dense green cover during the dry season protects the soil and decreases erosion by wind or rain. As green manure, it provides organic matter and minerals. It also fixes nitrogen into the soil thereby improving crop yields. Due to its drought tolerance, Lablab grows in a diverse range of environmental conditions (Valenzuela and Smith, 2002).

In Kenya, Lablab contributes highly to food security among the small scale farmers in rural areas where it is grown. Despite its importance, limited research has been conducted on the species as a food crop. The lack of information on genetic diversity of Lablab has immensely hindered its improvement in Kenya. Estimation of genetic diversity in a crop species is prerequisite for its improvement. The use of germplasm with distinct DNA profiles helps to generate breeding populations with broad genetic base (Singh *et al.,* 2012). In this study SSR markers were used to assess the genetic diversity of Lablab grown in Kenya.

MATERIALS AND METHODS

Plant materials

A total of 96 *Lablab purpureus* accessions were collected from the gene bank of Kenya, Rift Valley, Eastern, Coast, Western, Nyanza and Central provinces of Kenya. One (1) gramme of leaf tissue was harvested when seedlings developed the first two fully grown leaves. The leaf tissue was placed in eppendorf self-standing tubes each containing two ceramic beads. The tubes with beads and leaf tissue were placed in the geno-grinder machine (Benchtop homogenizer, Fast prep*-24) which was set to run for one minute at 4 up-down movements per second (4M/S). A modified of the cetyltrimethylammonium bromide (CTAB) method (Kimani *et al*., 2012) was carried out as described below. Nine hundred micro-liters (900µl) of extraction buffer (2% CTAB, 100mM Tris- Hydrochloric acid (HCl) pH 8.0,1.4M Sodiumchloride (NaCl), 50mM Ethylenediaminetetraacetic acid (EDTA), 2% Polyvinylpyrolidone (PVP) 10µ1 of 2% β-mercaptoethanol) was added to the leaf tissue and ground to form a slurry. The slurry was incubated at 65^{0}C for 15 minutes in a water bath with constant shaking. It was then centrifuged at 13000rpm for five minutes.

Six hundred microliters (600µl) of the supernatant were transferred into a fresh eppendorf tube and an equal volume of chloroform: isoamyl alcohol (24:1) was added. The eppendorf tubes were shaken well before separating the contents in a centrifuge at 13000rpm for 5 minutes. Five hundred microliters (500µl) of the aqueous phase was transferred into a fresh tube and an equal volume of chloroform: isoamyl alcohol (24:1) added. The tubes were shaken well and then centrifuged for 5 minutes at 13000rpm. Four hundred microliters (400µl) of the aqueous phase was transferred to a fresh tube and an equal volume of ice-cold isopropanol added, and mixed by inverting several times to precipitate the DNA. The tubes were centrifuged at 13000rpm for 5 minutes. The supernatant was decanted, leaving the DNA pellet at the bottom of the tube. The pellets were washed using 500µ l of 70% ethanol, and spun for 1minute before they were air dried for 1hour. The dried pellets were re-suspended in 50µl of sterile distilled water. RNA was removed by adding two microliters (2µl) of pancreatic ribonuclease A (RNase A) (10mg/ml) and incubating the samples for 1 hour at 37°C. The samples were stored at minus 20°C.

The quantity and quality of genomic DNA was examined by comparing the template DNA isolated from samples with a DNA ladder (gene ruler) of one kilo base (1 kb) in a 0.8% agarose gel using 1x TBE buffer and viewed in a gel box (G: Box, Syngene). The diluted DNA samples were subjected to polymerase chain reaction (PCR) in a thermocycler machine (Techne TC 412, Applied Biosystems Veriti systems) amplification using simple sequence repeat (SSR) markers specific for *Lablab purpureus* (Table I)

RESULTS AND DISCUSSION

Markers' effectiveness in detecting allele availability and polymorphism

In this study, a total of 43 alleles were detected and all were polymorphic (Table II). The number of alleles at a marker locus is related to the genetic diversity that can be revealed by a particular marker. The more alleles at a locus, the higher the degree of diversity that can be revealed and the more efficiently closely related genotypes can be distinguished (Nagy *et al*., 2012). SSR markers are locus-specific and generally amplify one locus (Gupta and Varshney, 2000). According to Shibairo *et al.,* (2015), heterozygosity is considered low if it is less than 0.4, moderate (0.4 - 0.7) and high when greater than 0.7. The expected heterozygosity at each polymorphic locus ranged from 0.23 (LabT6) to 0.46 (LabT1) and on average was 0.38 (Table II) indicating a low heterozygosity or a narrow genetic base of the Lablab accessions studied.

Polymorphic information content (PIC) provides an estimate of discriminatory power of a locus by taking into account not only the number of alleles expressed, but also the relative frequency of those alleles (Nagy *et al*., 2012). The highest PIC value of 0.67 was observed in SSR primers LabT3, LabT7 and LabT33 while the lowest PIC value of 0.58 was observed in primer LabT6 Table II). Polymorphic information content values range from 0 (which is an indicative of monomorphism) to 1.0 (very high discriminative power with many alleles in equal frequencies). The higher the PIC value, the more informative is the SSR marker (Nagy *et al*., 2012).

Genetic distance between populations of Lablab bean

Genetic distance is the difference between two entities that can be described by allelic variation or the extent of gene difference between populations or species (Nei, 1987). In this study, pairwise comparison of *Nei*'s unbiased genetic distance among the 15 populations ranged from a low of 0.092 between Embu and Meru populations to a high of 1.081 between Mwingi and Western populations (Table III). This implies that the Embu/Meru populations are closely related and this could be attributed to the nearness of these geographical regions hence there could be higher chances of local communities sharing the Lablab bean accessions as seed stock. The identified genetically distinct populations, for instance Mwingi and Western, could be potentially important sources of germplasm for further improvement programme in the Lablab genotypes in Kenya. Hybridizing selected members from the two populations could probably result to genotypes with high heterosis.

Genetic differentiation of populations

The extent of genetic differentiation was estimated between and within populations using F statistics of Wright, (1951). Three F coefficients are generally used in genetic diversity studies. These are: (F_{IT}) that estimates correlation of genes within individuals over all populations; (F_{ST}) that estimates correlation of genes of different individuals in the same population and, (F_{IS}) that estimates correlation of genes within individuals within populations (Muhamad *et al.,* 2003). (F_{ST}) equals zero when subpopulations are identical in allele frequencies and one when they are fixed for different alleles. (F_{ST}) is a measure of genetic differentiation over sub-populations and is always positive (Muhamad *et al.,* 2003). In this study the F_{ST} was generally low ranging from 0.188 to 0.399 with a mean of 0.270 (Table IV), implying that Lablab sub-populations used in this study did not have much difference in allele frequencies.

The NM is a measure of gene flow and ranged from 0.377 to 1.081 with a mean of 0.733 (Table IV). This indicates that there was high gene flow among the Lablab populations. This could have come about due to movement of seeds from one geographical region to another. This is also supported by the AMOVA (Table V) which denotes that most (85%) of the molecular variation in Lablab bean accessions was partitioned within populations, with lesser amounts (15%) partitioned among populations. A survey conducted in Lablab growing areas of Kenya in 2006 indicated that a substantial percentage (20.4%) of Lablab bean growers obtained seed from neighbours and markets (Kamotho *et al.,* 2010; Kinyua and kiplagat, 2012). Seed exchange for planting is common especially in crops that do not have structured certified seed production systems. This movement of seeds across regions is likely to have an impact on the gene flow in Lablab bean. Additionally, although Lablab is predominantly a self-pollinating crop which shows little inbreeding depression, significant levels (6-10%) of natural cross pollination occurs (Kukade and Tidke, 2014) which could also have contributed to gene flow.

Mean allelic analysis across the fifteen populations

An evaluation of diversity based on expected heterozygosity demonstrated that the highest population diversity existed among the Lablab bean accessions from Nairobi followed by Genebank-Eastern, Meru, Makueni, Nyeri, Murang'a, Thika, Riftvalley, Embu, Lamu, Machakos, Genebank-Coast, Mwingi, Nakuru and finally Western in that order (Table VI). Among the Lablab bean accessions analyzed for genetic diversity, accessions collected from Nairobi and Eastern region of Kenya but conserved at the genebank of Kenya showed the highest Shannon diversity index of $I = 0.96$ and $I = 0.90$, respectively, while accessions collected from Western and Nakuru exhibited the lowest index of 0.464 and 0.576 respectively (Table VI). The analysis of allelic patterns across the 15 Lablab bean populations revealed that accessions from Nairobi had the largest number of different alleles (*Na*) of 2.9. Since Nairobi is the capital city of Kenya, the high gene diversity found there could be attributed to the fact that it is a business hub region where traders of Lablab bean from all over the country converge.

Principal Coordinate and Cluster Analysis

The principal coordinate analysis was undertaken in order to confirm the clustering pattern obtained from unweighted pair group method with arithmetic averages (UPGMA) cluster analysis and exploit the resolving power of ordination. The 15 Lablab populations generally segregated with a high degree of overlap among them (Fig.1). This indicates similarity among the populations.

A dendrogram constructed (Fig. 2) on the basis of a genetic distance matrix and by unweighted paired group method with arithmetic averages (UPGMA resolved the 15 Lablab bean populations into two distinct clusters. According to the resultant dendrogram, fourteen populations were clustered into one cluster (B) while population number 15 (Western) which comprised of accessions from Bungoma and Kisumu separated on its own cluster (A) (Fig. 2).

Narrow genetic variation of genotypes may result during the long cultivation history of species as an adaptation to the local agro-climatic conditions (Seehalak *et al*., 2006). Farmers continuously select good seed for planting based on desirable agro-morphological traits such as yield, disease resistance, drought tolerance and earliness in maturity. Molecular markers are scattered throughout the genome and their association with various agronomic traits is influenced by the cultivator under selection pressure induced by domestication. Therefore, the need to design breeding programs with the aim of broadening the genetic base of Lablab bean is of paramount importance. This could be achieved by introgression of genotypes from the wild and also from different regions in Africa, Australia, and Asia.

TABLES AND FIGURES

Table I: List of ten SSR Primer Pairs (specific for *Lablab purpureus*) Used in the Study

Primer name	Primer Sequence Forward 5′-3′	Reverse 5′-3′	Expected product size (bp)	Tm°C	Repeat motif
Lab T1	ACCAGAATGGTTTCTCAAGTTCCT	GGTGAACCTTCCTACACCATGACT	273	56.1	(TA)7
Lab T2	GTGCGCGTCACTTATTAGTTCTTA	CAATATCTTCACGTAACCACGGTA	224	54.6	(TATATC)7
Lab T3	CAGATCGATTGGTAGCTGGATTTC	CCTCCTTACAGAAAGGGTAGCCTAGT	194	57.8	(TG)7
Lab T6	TCAATCGTTGTTGGAAGAGGGTAT	GTCTCCTTCAACTGTGTCCACTGA	187	57.5	(TGG)6
Lab T7	CAGCAGTGTTGCCTCATACAGAAC	TGTACTTAGCCAAGATCAGGCACA	123	57.5	(ATG)6
Lab T14	GGCATGGTGAAGATTGAAGAAGAG	AGAAGCAGAGGACAGGTGAATTGT	255	57.8	(GA)8
Lab T24	GATCAGCTCCAGACTGCTGACG	TAACCCTCCATTCATTGTCCATTC	202	58.5	(TC)7
Lab T25	GGGTTGAAGCTCACACAAATTCTT	CCAATGATGGTTGTATGAGTAGCAC	126	57.4	(TGGT)5
Lab T28	CTTTCTCCATGCAGACCAAACTTC	CCTGTAAATAACTGTCCTGGGAAGC	204	57.9	(ATG)6
Lab T33	CTAACCATGGCCTTGAGTGGTACT	AATGAGTGAATGCAGCAGTAG	345	57.3	(CTTTTC)5

Table II: Characteristics of the 10 Lablab SSR Markers Indicating Major Allele Frequency, Number of Alleles, Expected Heterozygosity and Polymorphism Information content (PIC)

Marker	Major Allele Frquency	Allele Number	Expected Heterozygosity	PIC
LabT1	0.3177	4.0000	0.4583	0.6530
LabT2	0.5000	5.0000	0.2292	0.6400
LabT3	0.3958	5.0000	0.4688	0.6715
LabT6	0.5313	4.0000	0.2083	0.5763
LabT7	0.3594	5.0000	0.4271	0.6701
LabT14	0.3698	4.0000	0.3021	0.6416
LabT24	0.4427	4.0000	0.4688	0.6133
LabT25	0.4115	4.0000	0.4271	0.6371
LabT28	0.4115	4.0000	0.4896	0.5838
LabT33	0.3698	4.0000	0.3229	0.6735
Mean	0.4109	4.3000	0.3802	0.6360

Table III: Lablab Pairwise Population Matrix of Nei's Genetic Distance

EMBU	GE_C	GE_E	LAMU	MAC	MAK	MERU	MUR	MWI	NAI	NAK	NYERI	RIFTV	THIKA	WEST	
0.000															EMBU
0.357	0.000														GEN_C
0.348	0.414	0.000													GEN_E
0.437	0.498	0.293	0.000												LAMU
0.614	0.712	0.272	0.317	0.000											MACH
0.435	0.341	0.223	0.271	0.370	0.000										MAK
0.092	0.343	0.312	0.352	0.549	0.346	0.000									MERU
0.402	0.459	0.138	0.342	0.235	0.200	0.371	0.000								MUR
0.536	0.678	0.247	0.298	0.572	0.351	0.557	0.332	0.000							MWI
0.373	0.160	0.326	0.434	0.577	0.169	0.280	0.351	0.506	0.000						NAI
0.348	0.521	0.478	0.527	0.863	0.520	0.485	0.430	0.318	0.426	0.000					NAK
0.384	0.532	0.193	0.386	0.413	0.194	0.225	0.121	0.382	0.255	0.464	0.000				NYERI
0.275	0.422	0.344	0.229	0.656	0.395	0.227	0.513	0.234	0.294	0.339	0.360	0.000			RIFTV
0.649	0.577	0.250	0.382	0.357	0.446	0.638	0.297	0.654	0.468	0.682	0.390	0.676	0.000		THIKA
0.483	0.542	0.446	0.496	0.627	0.358	0.336	0.553	1.081	0.409	0.966	0.487	0.651	0.588	0.000	WEST

Key: EMB: Embu, GENC: Genebank Coast, GENE: Genebank Eastern, MAC: Machakos, MAK: Makueni, MER: Meru, MUR: Murang'a, MWI: Mwingi, NAI: Nairobi, NAK: Nakuru, NYE: Nyeri, RIF: Rift Valley, TH: Thika, WEST: Western

Table IV: F-Statistics and Estimates Of Differentiation of all Lablab Bean Populations for Each Locus

Locus	F_{IT}	F_{ST}	F_{IS}	NM
LabT1	0.244	0.188	0.069	1.081
LabT2	0.401	0.399	0.004	0.377
LabT3	0.019	0.248	-0.305	0.757
LabT6	0.296	0.381	-0.136	0.407
LabT7	0.106	0.204	-0.123	0.978
LabT14	0.332	0.274	0.079	0.661
LabT24	0.139	0.215	-0.096	0.914
LabT25	0.257	0.309	-0.074	0.560
LabT28	0.142	0.213	-0.090	0.926
LabT33	0.274	0.273	0.002	0.667
Mean	0.221	0.270	-0.067	0.733
SE	0.037	0.023	0.036	0.076

Table V: Analysis of Molecular Variance (AMOVA) for 15 Populations of Lablab Bean and Partitioning of the Total Diversity into Population Components

Source of variation	df	TSS	MSS	Estimated Variance	Percent molecular variance (%)	P	PhiPT (ΦPT
Among Populations	14	258.445	18.460	1.567	15%	0.010	0.153
Within Populations	81	701.274	8.658	8.658	85%		
Total	95	959.719		10.225	100%		

PhiPT (ΦPT) = the estimate of population genetic differentiation based on permutation across the full data set, df = degree of freedom, TSS = total sum of squares, MSS = Mean sum of squares,

Table VI: Mean Number of Different loci (Na), Number of Effective loci (Ne) Expected Heterozygosity (He), Shannnon index (I) Across the 15 Lablab Bean Populations.

Mean	EM	GC	GE	LM	MC	MK	ME	MU	MW	NA	NA	NY	RV	TH	WE
Na	2.30	2.30	2.90	2.60	2.60	2.50	2.60	2.70	2.30	2.90	1.90	2.20	2.40	2.80	1.90
Ne	2.05	1.83	2.31	1.97	1.92	2.17	2.26	2.16	1.71	2.51	1.64	2.10	2.01	2.15	1.51
He	0.48	0.44	0.56	0.47	0.46	0.51	0.53	0.51	0.40	0.58	0.36	0.51	0.48	0.51	0.30
I	0.73	0.67	0.90	0.75	0.74	0.81	0.85	0.83	0.63	0.96	0.58	0.75	0.75	0.84	0.46

Key: EM: Embu, GC: Genebank Coast, GE: Genebank Eastern, MC: Machakos, MK: Makueni, ME: Meru, MU: Murang'a, MW: Mwingi, NA: Nairobi, NK: Nakuru, NY: Nyeri, RV: Rift Valley, TH: Thika, WE: Western

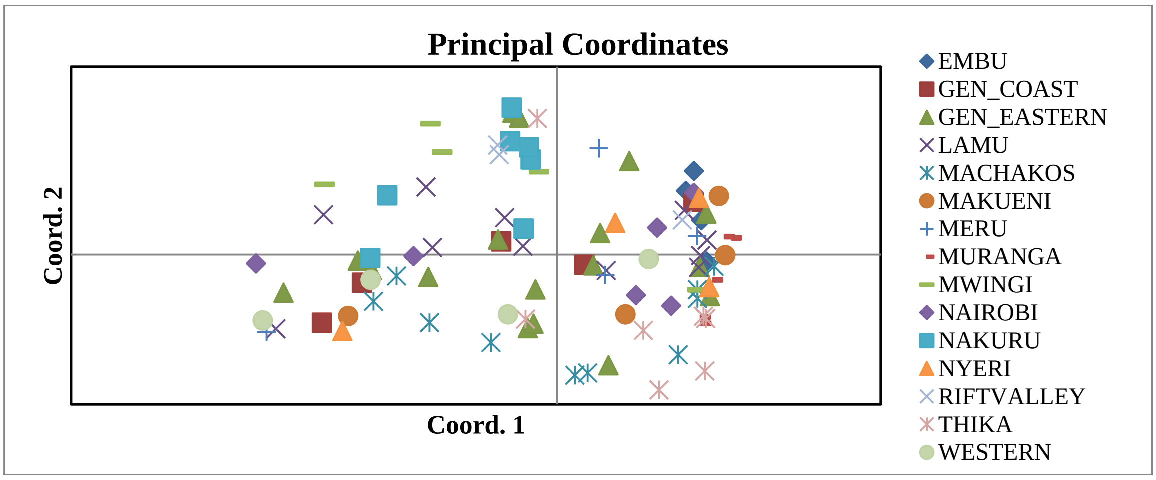

Fig.1: PCoA: Scatter plot showing the clustering pattern of 15 Lablab bean populations represented by different colours and symbols.
KEY: The 15 Lablab populations are Embu, Genebank-Coast, Genebank-Eastern, Lamu, Machakos, Makueni, Meru, Murang'a, Mwingi.

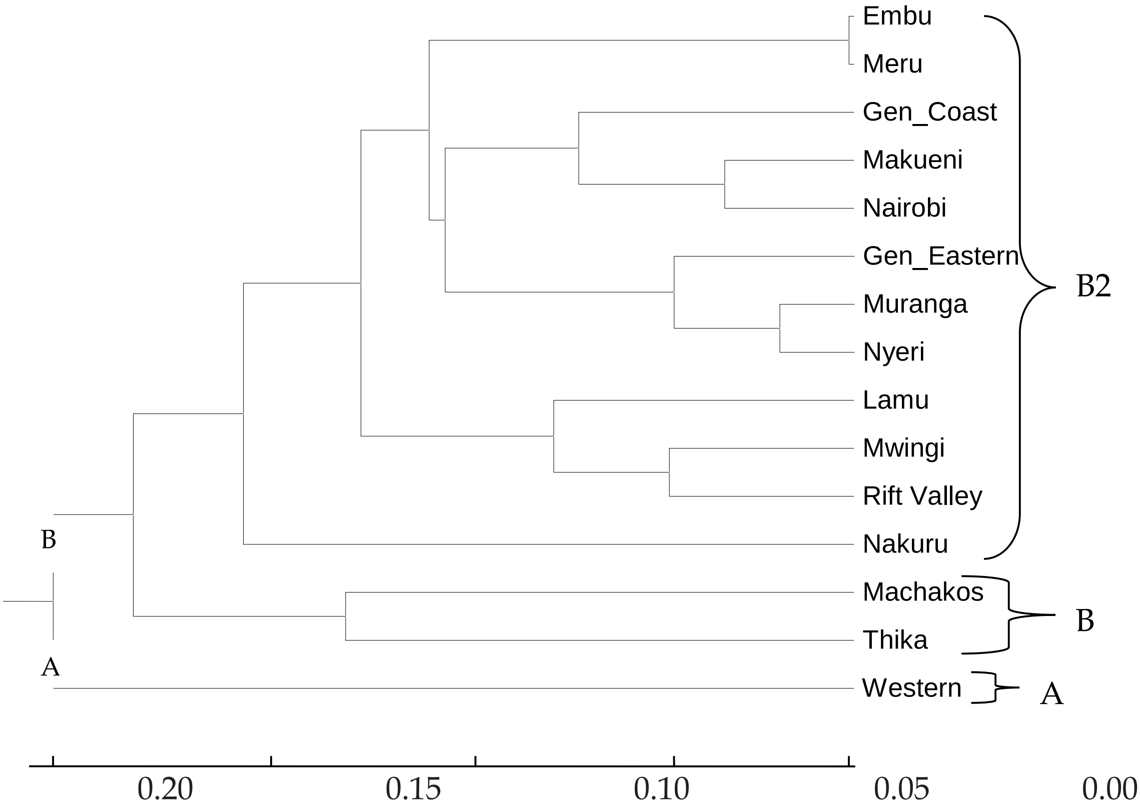

Fig.2: Genetic relationship among 15 populations of *Lablab purpureus* using dendrogram based on Darwin's genetic identity distance.

CONCLUSION

Lablab germplasm assayed by SSR markers is of narrow genetic base. Lablab bean populations from Mwingi and Western were found to be distantly related and therefore selected genotypes of desirable agronomic traits from the two populations could be hybridized to produce genotypes with probably high heterosis. Results of this study are expected to benefit Lablab bean breeding efforts in Kenya as well as aid in conservation of Lablab germplasm.

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9.4 Response of yield and yield components of maize as affected by tied ridges, fertilizers and cropping system in the semi- arid areas of Machakos County, Kenya

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ABSTRACT

Lack of enough soil moisture and depletion of nutrients in the soil as a result of continuous cropping and cultivation of soils without adequate use of external inputs is one of the major crop production limitations in the semi-arid areas of Kenya. An experiment was set up in Machakos County Kenya, in 2015 and 2016 to investigate the response of yield and yield components of maize to tied ridges, fertilizers and cropping systems. On average, tied ridges combined with 5t/ha of FYM and monocropping gave the highest grain yield (1.11t/ha) followed by conventional combined with FYM 5t/ha and monocropping (0.89t/ha); while the least was from conventional combined with FYM 0t/ha and intercropping (0.26t/ha). For the biomass fresh weight, the highest was given by tied ridges combined with FYM 5t/ha and monocropping (3.87t/ha); followed by tied ridges with FYM 5t/ha and intercropping (2.65t/ha) and the least was from conventional tillage with FYM 0t/ha and intercropping (1.40t/ha). The ears dry weight ranged from 1.36t/ha to 0.34t/ha with the highest from tied ridges combined with FYM 5t/ha and

monocropping (1.36t/ha).The least was 0.34t/ha which was produced from conventional tillage, FYM 0t/ha and intercropping. The highest Stover dry weight was given by tied ridges, FYM 5t/ha and monocropping (0.93t/ha) while the least was from conventional, FYM 0t/ha and intercropping (0.44t/ha).Generally, the effect of tied ridges, fertilizers and cropping system had a highly significant effect (p value = <0.001) on grain yield, biomass fresh weight, ears dry weight, stover and grain weight.
Key words: Tied ridges, fertilizers, cropping system, Growth, yield and yield components

INTRODUCTION

Food shortage as a result of declining yields and inadequate extreme fluctuations in the availability of water for plant growth in Sub- Saharan Africa is a common phenomenon among the smallholder farmers as reported by Baron et al.,(2005). According to Powlson et al., (2011), soil erosion is the major contributor to nutrient loss mostly where agronomic inputs are low, vegetation cover is scarce, soils are not resilient and also in places where heavy rain fall sometimes occur.Stoite et al., (2009) indicate that, soil erosion directly has an adverse impact on the productivity of the land as a result of loss of soil, water and nutrients. Reports by Shisanga et al., (2009) show that, soil impoverishment in Machakos County is also associated with poor farming practices and high costs of inorganic fertilizers. In addition, nutrient loss and water deficit mostly at the root zone is an important key factor that affects crop production (Bossio et al., 2010). According to Ngigi et al., (2006), increased soil moisture storage at the root zone (*situ* rain water conservation) reduces run- off and soil loss. According to literature, there is an important relationship between soil and water conservation and therefore it's important to address all of the concurrently. Soils in Machakos County are characterized by low water holding capacity and low organic matter. The average maize yield is less than 0.5t/ha (only 1/3 of the potential) as reported by NEMA, (2013). Therefore, combining tied ridges, fertilizers and cropping system may be a solution to effective sustainable crop production. This study was carried out to determine the effect of tied ridges, fertilizers and cropping system on the yield and yield components of maize in Machakos County.

MATERIALS AND METHODS

An experiment was conducted in KARLO Katumani in Machakos County, Kenya in short rainy season 2015 and long rainy season 2016. The treatments were: water conservation at two levels (Conventional and tied ridges), fertilizers at three levels (0t/ha FYM, 5t/ha FYM, and 20kgN/ha) and cropping system at two levels (monocropping and intercropping). The experiment was laid out in a randomized complete block design (RCBD) with plot sizes of 5.4m x 3.6m replicated four times. The tied ridges were imposed during land preparation. The spacing of the ridges was 90cm tied at 2.5m interval. The ridges were 20cm high and ties (cross ties) 20 cm high. Maize variety planted was KVD1 (a short duration seed with maturity between 85 to 100 days recommended for dry areas) and cow pea var. K.80. The maize seeds were sown 3 seeds per hole then thinned to 2 seeds at a spacing of 90cm x 30cm. The cowpea was sown 2 seeds per hill at 30cm between maize rows for the intercrop plots.Intial soil characterization before the start of the experiment was done and also the FYM used was analyzed. Triple super phosphate (TSP) at a rate of 60kg/ha was put in the planting holes in all the plots. Where FYM was a treatment, it was mixed with TSP. Calcium ammonium nitrate (CAN) was applied as a top dress at a rate of 20kg/ has in plots where it was a treatment. Other agronomic procedures in maize production were appropriately followed after planting. At maturity, maize was harvested from a net plot measuring 3.4m x 1.6m.The fresh plant biomass weight, ears fresh weight and stover fresh weight was taken using an electronic weighing balance; after which the ears and stovers were sampled, sundried and their dry weight taken and expressed on a 12.5% water content basis.

DATA ANALYSIS

The collected data was subjected to analysis of variance using Gens tart 15th Edition and the means were separated using Tukey's HSD at $p < 0.05$.

RESULTS

For the plant biomass fresh weight, the means ranged between 3.86t/ha to 1.16t/ha with tied ridges combined with 5t/ha FYM and monocropping producing the highest mean (3.86t/ha). This was followed by tied ridges with 5t/ha FYM and intercropping (2.65t/ha). Conventional tillage with 0t/ha FYM and intercropping recorded the lowest mean (1.16t/ha). In terms of the total number of ears /ha, the means ranged from 17002 ears/ ha to 11028 ears /ha with conventional tillage combined with 5t/ha FYM and monocropping registering the highest mean (17002 ears /ha). The second highest mean was recorded from tied ridges with 5t/ha FYM and monocropping (1654 ears/ha). The lowest mean was produced by conventional tillage with 5t/ha FYM and intercropping (11028ears/ha). The means for the ears weight ranged between 1.36t/ha to 0.34t/ha with tied ridges with 5t/ha FYM and monocropping recording significantly higher yields (1.36t/ha) followed by conventional tillage combined with 5t/ha FYM and monocropping while the lowest mean was registered by conventional tillage with 0t/ha FYM and intercropping. For the stover yield, the means ranged between 0.93t/ha to 0.44t/ha with tied ridges combined with 5t/ha FYM and monocropping recording significantly higher yields (0.93t/ha) and the second highest from conventional with 5t/ha FYM and monocropping. The lowest mean was gotten from tied ridges with 20kg N/ ha (0.44t/ha). For the grain yield, the means ranged between 1.11t/ha to 0.26t/ha with tied ridges with 5t/ha FYM recording the highest mean (1.11t/ha). Conventional tillage combined with 5t/ha FYM and monocropping produced the second highest yield (0.89t/ha) and the lowest grain yield was given by conventional with 0t/ha FYM and monocropping (0.26t/ha).

Table 1: Means of Effects of Tied Ridges, Fertilizers and Cropping Systems on the Grain and Yield Components of Maize

Treatment	Biomass Fresh Weight (t/ha)	Total No. of Ears/ ha	Ears Weight(t/ha)	Stover Yield (t/ha)	Grain Yield (t/ha)
Conventional + 0t/ ha FYM + Monocropping	2.142abcdef	16542a	0.9630abc	0.6073ab	0.6426ab
Conventional + 0t/ha FYM + Intercropping	1.160a	13326a	0.3395a	0.4669a	0.2592a
Conventional +5t/ha FYM + Monocropping	2.585abcdef	17002a	1.1033abc	0.8211ab	0.8897ab
Conventional + 5t/ha FYM + Intercropping	1.404ab	11028a	0.4090ab	0.4365a	0.3264a
Conventional + 20kg N/ha + Monocropping	2.369abcdef	15623a	1.0316abc	0.6760ab	0.8067ab
Conventional + 20 kg N/ha + Intercropping	1.342ab	12406a	0.3965ab	0.4714a	0.3079a
Tied ridges + 0t/ha FYM + Monocropping	1.889abcde	14244a	0.6609abc	0.5140ab	0.5240ab
Tied ridges + 0t/ha FYM + Intercropping	1.438ab	11947a	0.4246ab	0.4658a	0.3358a
Tied ridges + 5t/ha FYM + Monocropping	3.869f	16542a	1.3565c	0.9271ab	1.1106b
Tied ridges + 5t/ha FYM + Intercropping	2.647abcdef	14244a	1.00001abc	0.5318ab	0.8070ab

Tied ridges + 20kg N/ha + Monocropping	1.955abcdef	11947a	0.7747abc	0.5207ab	0.6244ab
Tied ridges + 20kg N/ha + Intercropping	1.579abcd	142449a	0.6038abc	0.4367a	0.4774ab
P value	< 0.001	0.184	< 0.001	< 0.001	< 0.001
e.s.e	0.6816	0.1193	0.121	0.0802	0.1012

*Means with the same letter in each column are not significantly different

DISCUSSION

Tied ridges combined with 5t/ha FYM gave significantly higher yields across all the treatments except for the total number of ears /ha. The increased yields with tied ridges may be attributed to reduced run-off since the rain water was trapped in the ridges and given time to slowly infiltrate in to the soil. As a result, nutrient loss was also reduced since run- off was minimized. The increased water infiltration increased moisture at the root zone; improving nutrient uptake hence higher yields. This is as opposed to conventional tillage where run-off took place carrying away soil nutrients reducing the amount of nutrients in the soil. The findings agree with those of Prinz, (2001) who also reported increased yields with use of tied ridges in maize production.

The plots with FYM registered higher yields as a result of increased source of organic matter in the soil which also improved the soil nutrients. The organic matter bound the soil particles together improving the water holding capacity of the soil and also the structure. This resulted in increased soil moisture for crop use hence higher yields. In plots with no FYM, the organic matter content remained low resulting to less soil nutrient hence reduced yields. The observation agrees with the findings of other researchers (Swift, 1997; Mutegi, 2012; Das et al., 1992; Tamayo et al., 1997 & Jate, 2012) who also observed increased yields as a result of FYM application. Mochoge et al., 1997 also reported increased maize yields of 700 and 1720kg/ha from plots treated with FYM.

Monocropping recorded higher yields since there was reduced competition for growth factors and therefore, the soil nutrients were adequate for the crop to perform better as opposed to where there was intercropping which led to completion of growth factors by the crops reducing the yields. The findings are in line with those of Hadter et al., (1991) who reported that, sole cropping produced higher yields than mixed cropping. Sawagogo kabore' et al., (2008) also observed that, monocropping had a significant yield increase. Other related results were reported by Twomlow et al., (2010) who reported an increased yield grains in maize monocropping.

Conclusion and Recommendations

Tied ridges combined with 5t/ha FYM had a highly significant effect (0.001) on the grain yield and its components apart from the total number of ears/ha. The combination also gave the highest stover and grain yield as compared to the other treatment. In order to exploit the potential of tied ridges as a water conservation practice, it ought to be combined with other soil and water management practices like use of FYM and monocropping system so as to maximize the yields. Farmers may adopt use of tied ridges combined with 5t/ha FYM and monocropping so as to maximize maize yields in consideration to other soil and water management practices.

Further research can be done to determine whether maize intercropped with a different legume apart from cow pea which was used in this study would give different results and also to explore other soil and water management practices suitable in this experimental site to exploit the effectiveness of tied ridges in conserving soil and water.

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